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Princeton, NJ

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IMPEDIMENTS TO ENERGY AND MATERIALS RECOVERY FACILITIES FOR MUNICIPAL SOLID WASTE

by

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Contract No. 68-03-2761

Project Officer

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16. ABSTRACT

Public anticipation that recycling would eventually solve the solid waste disposal problem, and simultaneously conserve natural resources, has persisted since enactment of the Resource Recovery Act of 1970 (P.L. 91-512). Progress toward these goals has fallen considerably behind initial expectations, however. Various explanations for the slow progress have been suggested, and federal research has focused mainly on the technological difficulties associated with resource recovery.

In 1978 the U.S. Environmental Protection Agency contracted with Mathtech, Inc., a subsidiary of Mathematica, to study the impediments to recycling municipal solid waste. The eight facilities selected for indepth analysis represented a cross-section of technologies, ownership types, geographical locations, and recovered products. None of the facilities were economical in the context of providing the least cost mode of disposal, and all eight facilities experienced net operating losses. A major impediment encountered by most of the facilities was competition from lower-cost landfills.

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report provides the case study of eight resource recovery facilities receiving municipal solid waste. Objectives of the study were to identify the impediments encountered by resource recovery plants and to evaluate the effects on financial performances of the selected facilities. The results of the study will assist community officials and waste managers in their decisions on whether to include resource recovery facilities in their overall solid waste management systems.

Francis T. Mayo
Director
Municipal Environmental Research
Laboratory

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ABSTRACT

Facilities designed to recover energy and/or materials from municipal solid waste can contribute to reducing the nation's dependence on exhaustible fossil fuels and virgin materials. Perhaps more importantly, such facilities also offer an alternative to direct landfill disposal of waste. Many cities and counties have thus begun to consider the feasibility of constructing and operating resource recovery facilities.

This study was undertaken to review the operations of a selected number of existing resource recovery facilities and thereby to evaluate the impediments to expanded recycling activity. The eight facilities selected incorporate a range of technologies, ownership arrangements, geographical locations and recovered products. Based on cost and performance data for the most recently completed fiscal year (generally 1978), none of the facilities was economical in the sense of providing the least costly mode of disposal. All of the facilities experienced net operating losses when capital costs were taken into account. Improved performance was projected for the subsequent fiscal year (generally 1979). One facility was expected to become profitable, and three other facilities were expected to become competitive with other waste disposal alternatives in their areas.

The most important impediment to economical operation was the pricing of landfill disposal below full social cost, a problem which should lessen with adoption of federal regulations for landfill disposal. To a lesser extent, other impediments contributed to reduced throughput, higher costs, and more limited markets than had been anticipated. In many cases, however, the facilities would not have been economical even in the absence of these impediments.

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SECTION 1

INTRODUCTION

Disposal of residential and commercial solid waste, commonly referred to as municipal solid waste (MSW), is a growing problem for the United States. It is estimated that about 140 million tons of MSW will require disposal this year [1], at a time when land which is suitable for sanitary landfill disposal is becoming increasingly higher priced due to competition from other uses. In some areas the remaining undeveloped land is environmentally unsuitable, aesthetically unacceptable, or located at considerable distances from points of waste generation. Many cities and counties have thus begun to look at alternative methods of disposal including the construction and operation of resource recovery facilities.

A resource recovery facility, at which MSW is processed to recover energy and/or materials, can potentially contribute to solution of the disposal problem by greatly reducing the volume of waste which must ultimately be disposed on the land. Volume reductions of up to 50 percent are possible, for example, with a shredding and ferrous recovery facility, 90 percent with an incineration and steam recovery facility, and 80 percent with an RDF (refuse-derived fuel) production facility [2]. Thus the large volume reductions obtainable with resource recovery can reduce the need for locating additional landfill sites.

Resource recovery facilities also contribute to reducing the nation's dependence on exhaustible fossil fuels and virgin materials. An incinerator burning MSW and recovering steam can produce 6 million Btu of steam from each ton of waste burned. This is more than can be produced from a barrel of oil or 6000 cubic feet of natural gas [3]. It would also be possible to recover as much as 10 million tons of ferrous scrap, 8 million tons of glass cullet, and 700,000 tons of aluminum scrap, if resource recovery facilities were in operation nationwide [4]. Reuse of this scrap in the manufacture of iron and steel, glass, and aluminum would yield savings in virgin materials from which these items are normally produced and also in the energy required in their production.

Despite the apparent promise offered by resource recovery facilities, the record to date has been disappointing. One recent source lists only 17 plants in full operation (plus another 12 under construction or in startup), beginning with a composting plant constructed in 1963 [5]. The aggregate processing capacity of these 17 plants is 6730 tons per day (about 400 tpd on average), or between 1.7 million and 2.4 million tons per year -- providing

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less than two percent of the nation's disposal requirements. Based on available information, none of the operating plants has consistently broken even financially — including the eight visited during this study. At least seven large corporations which had been involved in the design, construction, or operation of resource recovery facilities have left the industry [6].

Many factors have contributed to the disappointing showing of resource recovery facilities. Several excellent and recently completed studies evaluated the technical and institutional barriers to resource recovery [7]. Other recent studies conducted intensive investigations involving particular operational or experimental plants [8]. These studies generally did not base their analyses on actual operating experience, but relied on engineering estimates, bids on construction contracts, and other preliminary or hypothetical data. While some studies in the second group have dealt with actual operating experiences, none of these attempted a comparative analysis of the financial performance of several facilities in a detailed and systematic fashion [9]. Filling in this gap has been one of the principal objectives of this study.

OBJECTIVES AND GENERAL APPROACH OF THIS STUDY

The primary objective of this study was to identify and evaluate the impediments to economical resource recovery facilities for municipal solid waste. To accomplish this objective, three broad questions were addressed: First, are existing resource recovery facilities economical? Second, if they are not, what are the impediments to economical operation? And third, what changes would be necessary to make the facilities economical?

Are Existing Resource Recovery Facilities Economical?

There are a variety of ways to define the term "economical." Theoretically, one should define an economical resource recovery facility to be one which meets the standard benefit-cost criterion of operation with social benefits equal to or in excess of social costs. Unfortunately, practical use of this definition is quite difficult because it would require calculation of all the "true" social prices and costs. The approach instead taken in this study was to examine the performance of individual facilities to see whether they were economical in the sense of private revenues in excess of private costs. This might be termed the "accounting" or "private market" definition of economical. To carry out these calculations, output and financial data were assembled for a selected number of operational resource recovery facilities.

Unfortunately, there are practical problems even with the accounting definition of ecomomical. For example, the accounting definition does not prescribe a particular treatment for pricing of waste disposal activities. Thus, a town which requires collection vehicles to pay a tipping fee will show on its books considerably higher revenues than another similar town which finances disposal services through general taxation. To overcome this problem, the "net disposal cost per ton" was also computed for each facility. The net disposal cost for a facility was defined to be the total cost of operation (including annualized capital costs) less any revenues from the sale

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of recovered energy or materials. The net disposal cost per ton is thus comparable to a "breakeven tipping fee" (even though many facilities may charge a tipping fee which is less than this amount). Another test of whether the facility is economical can then be made by comparing the net disposal cost per ton at the facility with the price for other disposal alternatives in the immediate area.

The financial picture of existing resource recovery operations can be quite different, depending on whether capital costs are stated on an historical cost basis or on a replacement cost basis. It is the latter which reflects the cost of building and operating one of these facilities today, and hence is the cost that should be looked at by communities now contemplating resource recovery. Therefore, the net disposal cost at each facility was also recalculated on a capital replacement cost basis.

What Have Been the Impediments to Economical Operation?

The second area of inquiry in this study was to identify the impediments to economical operation. When the term "economical" is defined in the theoretical sense of social benefits in excess of social costs, then an "impediment" is any factor which causes the prices and costs faced by the facility to diverge from the true social prices and costs. There are two reasons why such divergences may occur. First, government policies (e.g., tax policy) may affect relative prices. For example, tax subsidies for virgin materials may artificially reduce the prices for these materials relative to the prices for secondary materials. Second, there may be imperfections in markets which prevent a resource recovery facility from facing correct prices. For example, if a municipality currently disposes its solid waste in an unsanitary landfill, the price it is willing to pay a resource recovery facility to accept its waste is too low by an amount equal to the social costs resulting from the health and aesthetic nuisances which are not borne by the landfill operator.

As noted previously, the ideal approach based on the theoretical definition described above is not feasible because the "true" social prices and costs cannot be readily calculated. Instead, the approach taken was to identify market and institutional factors which appear to have adversely affected the financial performance at each facility. This included comparing the actual revenue and expenditure performance at each facility with the performance anticipated in the original planning stages. The intention was not to second-guess the communities involved, but rather to find out where things went differently and why. To the extent that there were divergences between expected and actual performance, presumably these can be attributed to changes in government policy, changes in market conditions, or inaccurate analyses or assumptions in the original planning stages. Examples of each of these problems were present among the eight sites visited.

In order to take account of these effects, a catalog or checklist of factors which are commonly perceived to be impediments was developed from the literature on resource recovery. The performance of each facility visited was then reviewed to assess whether any of the listed impediments affected economic performance. Given the information available, judgments in some

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cases were made on a qualitative rather than quantitative basis, but these judgments nevertheless help clarify the relative importance of impediments to economical resource recovery.

What Changes Would be Necessary to Make the Facilities Economical?

A third area of inquiry in this study was to assess the sensitivity of the facilities' financial performance to changes in circumstances. Although a given facility may currently operate at a loss, increased revenues could erase these losses, and it would be useful to know the magnitude of change required to bring this about. For example, would a 10 percent increase in oil prices provide the necessary increase in steam revenues, or would it take a 50 percent increase? Would strict enforcement of RCRA* standards for landfills raise landfill costs to a level at which resource recovery would be more competitive, or is this unlikely to occur? Obviously, questions of this sort are extremely difficult, and one can only approximate the answers. However, the estimates, although approximate, should provide a clearer indication of the economic viability of resource recovery facilities as a method of solid waste disposal.

SELECTION OF SITES

In selecting sites for the eight case studies, the primary concern was to include a range of technical processes, ownership arrangements, sizes, products, and geographical locations. At least one year of operation (and preferably two or three), beyond the initial shakedown (breaking-in) period was also desirable so that the financial results would be representative. Resource recovery is a new industry, and it was difficult to find eight sites which fully met these criteria. Although the sites selected are not a random sample, hopefully the facilities are sufficiently representative to draw inferences concerning the effects of alleged impediments on the development of the industry as a whole.

The strengths and weaknesses of the case study approach may perhaps best be summarized by drawing attention to three difficulties encountered in the site selection process. First, selection of a site required obtaining the cooperation of the facility owners and/or managers. Some facilities were excluded because the data required were considered proprietary; study of other facilities was precluded because the facilities had been the focus of political debate locally; and the management of at least one facility refused to cooperate because too much staff time had been taken up in the past in accommodating researchers. Nevertheless, cooperation from many individuals in government, private industry, and academia made this study possible, and to these individuals deep appreciation is expressed.

A second problem in site selection is one of defining what constitutes a resource recovery facility. Some of the sites included in this study are not

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* The Resource Conservation and Recovery Act (1976).

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presently engaged in resource recovery to the extent they had originally anticipated, but it was considered important to include them to identify the factors which had prevented realization of original expectations. That is, some impediments might be overlooked if the study had focused solely on the more successful facilities. Furthermore, a broad perspective of what constitutes resource recovery was taken rather than restricting attention to currently popular methods. Thus, recovery of landfill gas was considered to be as much an example of resource recovery as other types of waste-to-energy systems, even though the latter are more widely practiced.

A third point regarding selection of sites is that the sample includes, in large part, facilities that employ what might be called first generation technology. This is to be expected since one of the selection criteria was that the facilities have one or more years of operation behind them. With the exception of the landfill gas recovery facility (Mountain View), all of the sites met this criterion. In an industry where technological advance may be rapid, conclusions based on facilities using first generation technology may not extrapolate correctly to later facilities. The reader should thus keep in mind that future developments in technology could potentially improve the outlook for resource recovery.

ORGANIZATION OF THE REPORT

The next section presents major findings and conclusions, followed by eight sections which describe the eight sites visited, present details of their operating results, and assess their economic viability. In general, the same format and approach is followed in each section except where data limitations or circumstances made this impractical. This was done in order to provide a systematic analysis of the eight sites, and to allow each section to be self-contained. Thus, some duplication of text may be encountered.

The eight site reports are followed by an appendix which catalogs and evaluates the impediments to resource recovery commonly mentioned in the literature. The catalog was prepared from the existing literature, and together with the case reports, provides the basis for the analysis and conclusions in the following sections.

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1. Doggett, R. M., et al. Forecasts of the Quantity and Composition of Solid Waste. EPA-600/5-80-001, International Research and Technology Corporation, 1980, p. 57.

2. The volume reduction estimates are based on operating experience at the various sites visited.

3. At a conversion efficiency of 85 percent, a barrel of oil would produce 5.3 million Btu of steam, while 6000 cubic feet of natural gas would produce 5.2 million Btu. This is based on 6.287 million Btu per barrel of residual fuel oil and 1021 Btu per cubic foot of natural gas. The latter estimates are from: U.S. Department of Energy, Monthly Energy Review, U.S. Government Printing Office, September 1979, p. 110.

4. Office of Technology Assessment. Materials and Energy from Municipal Waste. U.S. Government Printing Office, 1979, p. 46, Table 13.

5. Ibid., pp. 96-7.

6. The seven companies include: Allis-Chalmers, Carborundum, Continental Can, General Electric, Hercules, Monsanto, and Westinghouse. As this report was in its final stages, an eighth company, Combustion Equipment Associates, operator of the Bridgeport, Connecticut RDF facility, filed for bankruptcy.

7. See, for example, Office of Technology Assessment, op. cit.; Comptroller General of the United States, Conversion of Urban Waste to Energy, EMD-79-7, 1979; Tennessee Valley Authority, Solid Waste Management, PRS-38 (mimeo), 1978; and Gordian Associates, Overcoming Institutional Barriers to Solid Waste Utilization as an Energy Source, HCP/L-50172-01, 1977.

8. See, for example, the references cited at the end of each chapter in this report.

9. Shortly before the draft version of this report was completed, it was learned that the U.S. Conference of Mayors was initiating a similar comparative study.

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SECTION 2

CONCLUSIONS

SUMMARY

At the eight sites visited, the resource recovery facilities were found to be uneconomical in the most recently completed fiscal year. This was the case not only in the accounting sense of revenues less than expenditures, but also in the broader sense of failure to provide the least costly waste disposal alternative. Because the finances at most of the facilities appeared to be improving each year, a projection was made of the financial results for the fiscal year which was in progress at the time. The projection indicated that one facility would reach profitability, and three additional facilities would be able to provide waste disposal at a cost which is comparable with competing disposal alternatives in the area. Nonetheless, much of the apparent improvement in their financial situation can be attributed to the statement of their capital costs on an original cost basis. In a period when construction costs are rising faster than the general inflation rate, this will give a misleading view of reality. When their financial statements are restated on a replacement cost basis (the cost of building and operating the facility today), only one facility would still appear economical.

Among the impediments evaluated, the most important was the pricing of landfill disposal below full social cost (defined in terms of strict enforcement of RCRA standards). To a lesser extent, other impediments resulted in reduced throughput, higher costs, and more limited markets than were anticipated. In many cases, however, the facilities would not have been economical even in the absence of these impediments.

Economic success in resource recovery appears to depend more on successful energy recovery than on successful materials recovery, at current prices. Revenues from recovered materials would have to increase by much more than revenues from recovered energy, on a percentage basis, in order for existing facilities to become economically viable. Thus, prospects for future success at these facilities will depend on improved prices, sales opportunities, and rates of recovery for energy more than for materials. Many of the alleged impediments examined had little or no effect on the success of resource recovery operations, but some merit special attention. In particular, air quality regulations, the fragmentation of authority for solid waste management, and difficulties in locating and entering markets for recovered energy have hindered operations in several cases.

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Finally, there appears to be some evidence of a tradeoff in the short run between economic efficiency using technologies adapted from other industries and thermodynamic and/or material flow efficiency using newer technologies. The impact on cost of incorporating new technologies is difficult to quantify, but technical innovation may be inhibited at present by high risk and thus an expectation of limited returns.

FACILITIES VISITED

Conclusions presented in this section are based on detailed case studies of eight operational resource recovery facilities at various locations throughout the United States. A brief description of these facilities is presented in Table 1. The eight facilities in Table 1 are believed to be representative of existing recovery facilities throughout the country. Half are located in the Northeast, where more intense urban land use has led to greater problems in siting waste disposal activities in recent years; others are in areas with different regional land use patterns. Half the facilities are owned and operated by municipalities, the authority usually assigned responsibility for waste disposal management in the United States, but also included are ownership/operation by a county, a large corporation, an investor-owned utility, and a joint venture by a county and a small corporation. All of the facilities were built within the last ten years and employ a variety of technologies in current use. Plant capacity for the eight facilities ranges from 100 tpd to 1600 tpd, a range which would probably match the disposal requirements for most communities with populations between 50,000 and one million. The purpose in selecting this variety of examples for investigation was to allow examination of recovery operations under different circumstances, and not to make judgments about particular facilities. It was beyond the scope of this study, for example, to determine whether public or private ownership is preferable, or whether waterwall incineration is more or less economical than RDF production, since different communities will find different arrangements appropriate.

ORGANIZATION OF THIS SECTION

The remainder of this section summarizes the results obtained from the case studies described in Sections 3 through 10 and offer interpretations of these results in terms of impediments described in the Appendix. These conclusions are organized here as responses to three broad questions: First, are existing resource recovery operations economical? Second, if they are not, what have been the impediments to economical operation? And third, what changes would be necessary to overcome these impediments?

One should always keep in mind that resource recovery facilities must compete in at least two markets simultaneously. They compete with landfills in the disposal market, and with extractors of virgin materials (including energy extractors) in the product markets. Consequently, resource recovery can be viewed either as an alternative means of disposal or as an alternative source of energy and materials. In this study it is viewed as a means of disposal (so that the standard of comparison is net disposal cost per ton of waste) for several reasons. First, a recovery facility is likely to be a dominant participant in the local disposal market in which it participates,

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TABLE 1. SUMMARY DESCRIPTION OF CASE STUDY FACILITIES

Project location	Owner/operator	Facility type	Capacity (tpd)	Products	Start date
Harrisburg, Pennsylvania	city	waterwall incineration	720	steam, ferrous	8/72
Braintree, Massachusetts	town	waterwall incineration	240	steam	3/71
North Little Rock, Arkansas	city	modular incineration	100	steam	9/77
Monmouth County, New Jersey	county	shredding	80 tph	ferrous	10/76
New Castle County, Delaware	county/ AENCO, Inc.	shredding	140 tph	ferrous	9/72
Ames, Iowa	city	RDF	400	RDF, ferrous, paper	9/75
Milwaukee, Wisconsin	Americology Div. of American Can Company	RDF	1600	RDF, ferrous paper	1/77
Mountain View, California	Pacific Gas & Electric Company	landfill gas recovery	1 Mscfd	pipeline gas	5/78

RDF = refuse-derived fuel
tpd = tons per day
tph = tons per hour
Mscfd = million standard cubic feet per day

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but equally certain to capture only a very small share of any product market. Since this implies that it is likely to be a price setter in the former and a price taker in the latter, it is disposal cost, rather than product cost, which is relevant to pricing. Second, although one of the facilities studied (Mountain View, California) is fully integrated into its product market, integration with the waste disposal customer is more typical. That is, one more often sees municipal governments engaging in resource recovery rather than energy or materials producers. The reasons for this are many, but include the fact that municipal governments typically have responsibility for waste disposal and limited options for discharging the responsibility. Energy and materials producers, on the other hand, have a wider range of options and in any case could not rely solely on resource recovery to satisfy market demand for energy and materials. To put this another way, resource recovery may ultimately provide a solution to the waste disposal problem; it will not by itself provide a solution to the energy crisis or raw materials shortages.

ARE RESOURCE RECOVERY FACILITIES ECONOMICAL?

Profitability Test

In the accounting sense of producing revenues in excess of costs, none of the eight facilities was economical in the most recently completed fiscal year (generally 1978) at the time visited. As shown in Table 2, the loss on a per ton basis ranged from $0.60 to over $36. Some care should be taken in making comparisons across facilities shown in the table, however, because of differences in accounting systems, financing techniques and other circumstances peculiar to each site. Data were adjusted to account for these differences and to standardize where possible, but some problems of non-comparability still remain.

Other special circumstances are also reflected in the results shown for each site. For example, the Braintree operation had only recently reopened after being closed for repairs to bring the facility into compliance with new air quality regulations adopted by the state. The Ames facility was closed for seven weeks while major modifications and repairs were being made following an explosion, and the Mountain View facility was still in the demonstration stage.

One other feature of the table should also be noted. Where the data were available, per ton amounts were calculated on the basis of received tonnage. This provides the best overall picture of the disposal operation. Four of the facilities, however, keep their records primarily on the basis of tons processed, which is generally less than received tonnage by the amount sent directly to landfill. For the three incinerators, the received tonnage is likely to be on the order of 5 to 10 percent higher than the amount recorded as processed tonnage; for the RDF facility, about 10 percent higher. The per ton costs in these cases may thus be overstated by approximately these percentages.

The special circumstances referred to above may be regarded as atypical operating problems in the sense that they are not expected to be recurring (although if data were available for a sufficiently long time period it might

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TABLE 2. ACTUAL FINANCIAL RESULTS FOR THE MOST RECENTLY COMPLETED FISCAL YEAR[1] ($ton)[2]

	Capacity (tpd)	Tons received/ processed (ktpy)	Total Cost[3]	Total revenue[4]	Net profit (loss)
Harrisburg, PA (waterwall incineration)	720	* /125	18.02	12.12	(5.90)
Braintree, MA (waterwall incineration)	240	* / 26	46.91	10.74	(36.17)
North Little Rock, AR (modular incineration)	100	* / 16	19.27	13.17	(6.10)
Monmouth County, NJ (shredding)	80 tph	65/ 44	15.85	3.90	(11.94)
New Castle County, DE (shredding)	140 tph	368/155	7.77	7.17	(0.60)
Ames, IA (RDF)	400	* / 37	30.59	13.11	(17.49)
Milwaukee, WI (RDF)	1600	301/124	24.31	14.34	(9.97)
Mountain View, CA[5] (landfill gas)	1 Mscfd	35[6]	1.42	0.38	(1.04)

1. Generally 1978.
2. Per ton received; or per ton processed where indicated by an asterisk.
3. Includes annualized capital cost.
4. Includes disposal fees.
5. Includes gas recovery operation only; landfill operation excluded.
6. Million standard cubic feet.

tpd = tons per day
tph = tons per hour
ktpy = 1000 tons per year
Mscfd = million standard cubic feet per day

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be possible to adjust figures for each facility for "expected rate of extended downtime" or some such category). Table 3 provides a projection of the financial results for the fiscal year (generally 1979) which was in progress at the time, on the assumption that the "atypical" results reflected in Table 2 would not persist. The results in this table represent an extrapolation to a full year, from data available for only part of the year. Despite the additional error which this may introduce, the resulting figures generally provide a more representative picture of the financial situation at each site. At Harrisburg, for example, revenues are projected to rise substantially because a new steam line was added and steam sales were begun just prior to the beginning of the year. At Braintree, the air pollution control modifications had been completed and an expanded operating schedule was introduced. At several of the other facilities, equipment availability and throughput had improved over the previous year. Only the North Little Rock facility, which was closed in mid-year for labor-related reasons, was expected to show atypical performance. Nonetheless, despite the forecast of potentially improved results at the various sites, only one — Mountain View — is likely to have reached breakeven operation.

Net Disposal Cost Test

As noted previously, differences in the way the various facilities account for disposal revenues (e.g., fees are paid directly in some instances and through general taxation in others) make it difficult to identify the true cost of disposal and to compare this cost with other disposal alternatives available. For this reason the net disposal cost per ton at each facility was calculated. The net disposal cost at a facility is defined to be total cost, less any revenues from energy or materials recovery. It is thus equivalent to the breakeven tipping fee. The net disposal cost for each facility is shown in Table 4 for the most recently completed fiscal year.

An examination of Table 4 indicates that with only one exception (New Castle County), all of the facilities were charging a tipping fee which was less than the net cost of disposal. While this is generally done in order to be competitive with surrounding disposal alternatives so that higher levels of throughput can be achieved, it does mean that waste disposal is being partially subsidized out of general taxation or, in the case of the privately-owned facilities, out of corporate profits. Table 4 also indicates that the net cost of disposal at each facility was generally higher than the cost of competing disposal alternatives in the immediate area (generally landfills or transfer stations). Again, the one exception to this statement is New Castle County, where all other landfills were closed by the county government.

Table 5 shows the projection of net disposal cost for the fiscal year in progress at the time. Note that with only one or two exceptions, the net disposal cost will have declined in comparison with the previous year. Table 5 indicates that four facilities are likely to have reached a point at which the net disposal cost will have fallen to a level comparable to the tipping fee that they charge. These facilities include Harrisburg, New Castle County (which had achieved this in the previous year), Ames, and Mountain View. In addition, Braintree, New Castle County, Ames, and Mountain View should also reach a level at which the net cost of disposal is comparable to other

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TABLE 3. PROJECTED FINANCIAL RESULTS FOR THE CURRENT FISCAL YEAR[1] ($/ton)[2]

	Capacity (tpd)	Tons received/ processed (ktpy)	Total Cost[3]	Total revenue[4]	Net profit (loss)
Harrisburg, PA (waterwall incineration)	720	* /140	21.17	18.57	(2.60)
Braintree, MA (waterwall incineration)	240	* / 48	22.24	11.35	(10.89)
North Little Rock, AR (modular incineration)	100	* / 8	20.61	12.44	(8.17)
Monmouth County, NJ (shredding)	80 tph	94/ 63	11.98	4.03	(7.96)
New Castle County, DE (shredding)	140 tph	340/131	9.81	7.87	(1.94)
Ames, IA (RDF)	400	* / 48	24.83	14.23	(10.60)
Milwaukee, WI (RDF)	1600	305/160	26.70	17.52	(9.18)
Mountain View, CA[5] (landfill gas)	1 Mscfd	229[6]	1.76	2.52	0.76

[1] Generally 1979.

[2] Per ton received; or per ton processed where indicated by asterisk.

[3] Includes annualized capital cost.

[4] Includes disposal fees.

[5] Includes gas recovery operation only; landfill operation excluded.

[6] Million standard cubic feet.

tpd = tons per day
tph = tons per hour
ktpy = 1000 tons per year
Mscfd = million standard cubic feet per day

TABLE 4. ACTUAL NET DISPOSAL COST FOR THE MOST RECENTLY COMPLETED FISCAL YEAR[1]
($/ton)[2]

	Capacity (tpd)	Tons received/ processed (ktpy)	Total cost[3]	Recovery revenue	Net cost of disposal[4]	Tipping fee	Lowest priced alternative
Harrisburg, PA (waterwall incineration)	720	* /125	18.02	.74	17.28	10.80 to 12.80	4.50 to 7.50
Braintree, MA (waterwall incineration)	240	* / 26	46.91	2.58	44.33	8.00	17.00 to 20.00
North Little Rock, AR (modular incineration)	100	* / 16	19.27	9.82	9.45	3.33	3.33
Monmouth County, NJ (shredding)	80 tph	65/ 44	15.85	0.03	15.82	4.00 to 5.75	2.50 to 7.50
New Castle County, DE (shredding)	140 tph	368/155	7.77	0.00	7.77	7.00 to 8.50	None
Ames, IA (RDF)	400	* / 37	30.59	12.35	18.24	0.25 to 18.00	8.00 to 12.00
Milwaukee, WI (RDF)	1600	301/124	24.31	2.16	22.03	10.68	8.00 to 12.00
Mountain View, CA[5] (landfill gas)	1 Mscfd	35[6]	8.26	0.38	7.88	6.84	6.84

1. Generally 1978.
2. Per ton received; or per ton processed where indicated by asterisk.
3. Includes annualized capital cost.
4. Total cost, less recovery revenue and less royalties, if any.
5. Includes both gas recovery and landfill operation, with latter included at cost of tipping fee.
6. Million standard cubic feet.

tpd = tons per day
tph = tons per hour
ktpy = 1000 tons per year
Mscfd = million standard cubic feet per day

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TABLE 5. PROJECTED NET DISPOSAL COST FOR THE CURRENT FISCAL YEAR[1] ($/ton)[2]

	Capacity (tpd)	Tons received/ processed (ktpy)	Total cost[3]	Recovery revenue	Net cost of disposal[4]	Tipping fee	Lowest priced alternative
Harrisburg, PA (waterwall incineration)	720	* /140	21.17	7.14	14.03	10.80 to 12.80	4.50 to 7.50
Braintree, MA (waterwall incineration)	240	* / 48	22.24	3.24	19.00	8.00	17.00 to 20.00
North Little Rock, AR (modular incineration)	100	* / 8	20.61	9.15	11.46	3.33	3.33
Monmouth County, NJ (shredding)	80 tph	94/ 63	11.98	0.03	11.95	4.00 to 5.75	2.50 to 7.50
New Castle County, DE (shredding)	140 tph	340/131	9.81	0.00	9.81	8.40 to 10.20	None
Ames, IA (RDF)	400	* / 48	24.83	13.43	11.40	0.25 to 18.00	8.00 to 12.00
Milwaukee, WI (RDF)	1600	305/160	26.70	3.67	22.78	12.18	8.00 to 12.00
Mountain View, CA[5] (landfill gas)	1 Mscfd	229[6]	8.60	2.52	5.88	6.84	6.84

1. Generally 1979.
2. Per ton received; or per ton processed where indicated by an asterisk.
3. Includes annualized capital cost.
4. Total cost, less recovery revenue and less royalties, if any.
5. Includes both gas recovery and landfill operation, with latter included at cost of tipping fee.
6. Million standard cubic feet.

tpd = tons per day
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disposal alternatives in the area. Although generalization about the relative merits of different technologies is difficult to establish from so few examples, it is interesting to note that the four facilities in each instance make use of a different technology, and that each technology on the chart — incineration, shredding, RDF, and landfill gas recovery — is represented.

Replacement Cost Test

While Table 5 suggests that resource recovery facilities are beginning to look like promising alternatives for waste disposal in a number of cases, it should be recognized that some of this promise is due to inflationary trends which distort financial analyses based on conventional methods of accounting for capital investments. This is a phenomenon which affects not only the resource recovery industry but also business activity in general. As a result, the Securities and Exchange Commission (SEC) and the Financial Accounting Standards Board (FASB) have begun to require businesses to prepare financial statements which adjust for the effects of inflation. The basic problem is one of restating capital expenditures on the basis of replacement cost (what it would cost to construct the facility today) rather than on the basis of original cost, as is the usual practice. In general, if construction costs have escalated at a faster rate than other revenue and expense categories since the original construction period, then the financial picture will appear worse compared to the original cost basis. If construction costs have escalated at a slower rate, then the financial picture will appear better than the historical cost basis. Table 6 provides a recalculation of the net disposal cost for each facility on a replacement cost basis. The recalculation was done for the fiscal year which was in progress at the time of the visit and thus corresponds to the data provided previously in Tables 3 and 5.

As can be seen in Table 6, the net disposal cost is higher at every facility when restated on a replacement cost basis. The magnitude of the increase in each case depends on both the number of years since the facility was originally constructed and on the proportion of total costs which are capital costs. Note that in only one case is the net disposal cost comparable to the current tipping fee (Mountain View). This is an anomaly, however, because in the absence of information on the replacement cost for the landfill portion of the operation, the landfill was included at its original cost. Two other facilities have a net disposal cost which is close to the upper range of their current tipping fee schedule (New Castle County and Ames). None of the facilities, however, has a net disposal cost which is comparable to the cost of other disposal alternatives in the area except New Castle County (which has closed all competing landfills) and Mountain View (which is somewhat misleading for the reason mentioned earlier). In effect, this means that if these eight communities were going to invest in resource recovery facilities, it is better to have done so when they did rather than to have waited until 1979.

For communities which may now be considering resource recovery facilities for waste disposal, the replacement cost figures presented in Table 6 are the most appropriate ones to examine. They provide the best indication of costs of building and operating a resource recovery facility in the current year.

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TABLE 6. PROJECTED NET DISPOSAL COST FOR THE CURRENT FISCAL YEAR,[1] ORIGINAL COST VS. REPLACEMENT COST BASIS[2] ($/ton)[3]

	Original cost basis			Replacement cost basis			
	Total cost[4]	Recovery revenue	Net cost of disposal[5]	Total cost[4]	Net cost of disposal[5]	Tipping fee	Lowest priced alternative
Harrisburg, PA (waterwall incineration)	* 21.17	7.14	14.03	27.56	20.42	10.80 to 12.00	4.50 to 7.50
Braintree, MA (waterwall incineration)	* 22.24	3.24	19.00	31.57	28.33	8.00	17.00 to 20.00
North Little Rock, AR (modular incineration)	* 20.61	9.15	11.46	23.17	14.02	3.33	3.33
Monmouth County, NJ (shredding)	11.98	0.03	11.95	12.59	12.56	4.00 to 5.75	2.50 to 7.50
New Castle County, DE (shredding)	9.81	0.00	9.81	10.92	10.92	8.40 to 10.20	None
Ames, IA (RDF)	* 24.83	13.43	11.40	33.94	20.50	0.25 to 18.00	8.00 to 12.00
Milwaukee, WI (RDF)	26.70	3.67	22.78	29.19	25.27	12.18	8.00 to 12.00
Mountain View, CA[6] (landfill gas)	8.60	2.52	5.88	9.17	6.45	6.84	6.84

1. Generally 1979.
2. Cost of duplicating the facility in 1979.
3. Per ton received; or per ton processed where indicated by an asterisk.
4. Includes annualized capital cost.
5. Total cost, less recovery revenue and less royalties, if any.
6. Includes both gas recovery and landfill operation, with latter included at cost of current tipping fee in both original and replacement cost figures since replacement cost of landfill is unknown.

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The figures suggest that until some of the impediments to economic resource recovery facilities, discussed in the next section, are ameliorated, the construction of resource recovery facilities may not be the most economical approach to waste disposal in many communities. This rather negative conclusion may be tempered somewhat by taking into account that recent revisions in federal income tax laws and regulations now provide an additional investment tax credit and a shorter depreciation period for investments in resource recovery facilities. The figures presented in Table 6 do not take these improved tax incentives into account. On the other hand, these tax incentives would be of benefit only in those instances where a private corporation owned the facility. In the more usual case where the facility is owned by a local government, the new tax provisions will not affect the financial picture suggested in Table 6.

Despite the past record of unprofitability, plant personnel and company or municipal officials at the facilities are generally hopeful about future prospects for their operations. These hopes were most often tied to being able to hold down tipping fees compared to landfill disposal sites with which they compete, obtaining increased revenue from recovered energy as energy prices continue to rise faster than their operating costs, and entering new markets for recovered products. It is beyond the scope of this study to speculate on whether these expectations will be realized.

WHAT HAVE BEEN THE IMPEDIMENTS TO ECONOMICAL OPERATION?

The Appendix contains a catalog of impediments to economical resource recovery developed from the existing literature. At each facility the impediments which had evident effects on the operation were noted, and a judgment was made as to whether the evidence pointed to the effects having been large. Table 7 lists the various impediments catalogued in the Appendix, along with the number of facilities at which these impediments were observed. The following discussion summarizes the results presented in this table.

Restrictions on Quantity or Composition of Waste

The most important impediment to economically successful resource recovery at the facilities visited was the pricing of landfill disposal below full social cost, defined as the cost of operating a landfill in accordance with provisions of the Resource Conservation and Recovery Act of 1976 (RCRA). The exceptions to this were Milwaukee, where the facility has a sufficient and guaranteed supply of waste that matches plant capacity; Mountain View, where the required waste is already in place; and New Castle County, where the county closed all other landfills. At most of the other locations, sanitary landfills are still a low-priced alternative to resource recovery, with the result that recovery facilities cannot attract sufficient quantities of waste to operate at or near capacity, or else are forced to lower tipping fees below net disposal cost in order to compete with landfills.

Fragmentation of authority for solid waste disposal hindered recovery operations at Harrisburg, Braintree, and New Castle County. Absence of disposal agreements with neighboring towns reduced the quantity of waste going to the first two of these, and uncertainty about policies of the state

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TABLE 7. IMPEDIMENTS TO ECONOMICAL OPERATIONS

Impediment	No effect evident	Some effect probable	Large effect probable
Restrict quantity or composition of waste			
Pricing of landfills below full social cost	3	1	4
Independent source-separation programs	8	0	0
Returnables policy for bottles and cans	7	1	0
Fragmentation of local government	4	4	0
Restrictions on interstate movement of waste	8	0	0
Seasonal or business cycle fluctuations	7	1	0
Increase initial cost or restrict design			
Inadequacies of available technology	3	3	2
High unit cost for equipment and parts	6	0	2
Limited design experience	3	4	1
Limitations on municipal financing	7	1	0
Low first cost approach to public contracting	8	0	0
Affect cost or efficiency of operations			
Limited operating experience	5	3	0
Limited availability of spare parts	7	1	0
Shortage of required labor skills including supervision	7	1	0
State and federal regulation of air quality	4	4	0
Restrictions on disposal of ash and residue	5	3	0
Limit markets for available products			
Siting restrictions	7	1	0
Franchise restrictions on steam and electric sales	8	0	0
Tax subsidies for virgin materials	1	7	0
Price controls on oil and gas	4	4	0
Lack of futures markets for scrap	8	0	0
Unpriced mining and processing costs	8	0	0
Differential freight rates	7	1	0
Lack of product standards for reclaimed materials	7	1	0
Rate regulation of electric utilities	6	2	0
Restrictions on use of ash, residue and shredded materials	5	3	0
Product labeling restrictions	8	0	0
Government procurement policies	8	0	0

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government contributed to reduced investments at the latter two. The other five facilities all draw on waste generated in more than one town, so they have evidently been able to overcome any division of responsibility present. In general, resource recovery involves scale economies to a degree that usually requires cooperation on a regional level, while waste collection tends to be organized at the municipal level, where volumes of waste are smaller than required for successful resource recovery except in larger cities.

Other impediments often cited as restricting the quantity or composition of waste had little effect. Independent source-separation programs were present in at least half the locations studied, but the amount of waste diverted appeared to affect recovery operations in only one instance (diversion of bundled newspaper in Milwaukee). At Ames, the state bottle bill has probably had some effect on revenues from recovered materials; at Milwaukee the operator is contractually protected from the effects of any future legislation concerning beverage containers. Restrictions on interstate movement of waste could conceivably affect facilities at Braintree and New Castle, but if anything they have probably helped rather than hindered operations. Seasonal waste fluctuations cause some rescheduling of winter operations in Milwaukee, but have not materially affected operations in the other cities.

Increased Initial Costs or Design Restrictions

The impact on initial cost of recovery facilities which results from incorporating new technologies is difficult to quantify, but it appears that this problem has been more acute at the two facilities which have attempted RDF and materials recovery. This is because other recovery technologies are adaptations of older, more developed technologies in which solid waste is substituted for some other material. For example, landfill gas recovery equipment is similar to natural gas processing equipment; solid waste shredders are similar to wood shredders; and waterwall incinerators are similar to steam generating equipment fired by coal or wood waste. Municipal solid waste is a highly heterogeneous material, and the adaptations involve either preprocessing to a homogeneous material (e.g., landfill gas) or else direct substitution of solid waste for some other material. This simplifies plant design and reduces cost, but it also reduces energy efficiency. RDF production is an attempt to develop a more transportable fuel by separating out the waste fraction with high energy content. Unfortunately, the materials handling process this entails is of such complexity that redesign and modification of equipment are often required.

Some of the consequences of these design considerations can be seen in Table 8, which presents data on capital costs at the facilities visited. By any standard, the landfill gas recovery facility was by far the least expensive, but it was also the least efficient in terms of energy recovery. Only about 10 percent of the energy in solid waste can be extracted through methane recovery, compared to around 60 percent through incineration. In terms of how capital costs are expended, incineration facilities cost more for boilers and delivery systems, and less for preprocessing systems compared to RDF facilities. Since Mountain View is likely to become economically viable before the other seven facilities, it appears that at the present level of

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TABLE 8. RESOURCE RECOVERY FACILITY CAPITAL COSTS
(Original dollars and 1979 dollars)

	Capacity (tpd)	Total capital cost ($1,000,000)		Capital cost per ton ($1,000 per ton per day)		Capital expenditures ($1,000,000)
		Original cost	Replacement cost	Original cost	Replacement cost	
Harrisburg, PA (waterwall incineration)	720	14.1	28.1	20.	39.	plant: $10.9 (1969) steam line: $3.2 (1977)
Braintree, MA (waterwall incineration)	240	3.3	7.5	14.	31.	plant: $2.8 (1968) ESP's, etc.: $0.5 (1976)
North Little Rock, AR (modular incineration)	100	1.5	1.9	15.	19.	plant: $1.5 (1976)
Monmouth County, NJ (shredding)	400[1]	3.6	5.3	9.0	13.	plant: $3.6 (1974)
New Castle County, DE (shredding)	1200[1]	7.0	10.2	5.8	8.5	plant: $2.0 (1972) other: $5.0 (various dates)
Ames, IA (RDF)	400	7.0	10.9	18.	27.	plant: $4.7 (1975) power plant mods.: $1.6 (1975) other mods.: $0.7 (1976-78)
Milwaukee, WI (RDF)	1600	28.9	34.6	18.	22.	plant: $18.2 (1976) power plant mods.: $5.0 (1976) other mods.: $5.7 (1978-79)
Mountain View, CA[2] (landfill gas)	1 Mscfd	0.85	1.0	nm	nm	plant: $0.84 (1977) added wells: $0.01 (1979)

1. Disposal capacity including landfill.
2. Includes gas recovery operation only; landfill excluded.

nm = Not meaningful.

Mscfd = Million standard cubic feet per day.

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technological development it may be economically efficient to skim off the most accessible energy available from solid waste with the least complex method available rather than to attempt thermodynamic efficiency as well. However, technological advances may change this situation.

Finally, institutional restrictions such as limitations on municipal financing and low-bid requirements for public contracting produced no discernible effects at the facilities visited, although the perceived level of risk was a factor in the decision by the City of Milwaukee to incur the added cost of private ownership.

Effects on Cost or Efficiency of Operations

Air quality regulations have been a double blow to resource recovery. Emission regulations have increased the cost of incinerating solid waste by necessitating expensive equipment such as electrostatic precipitators to control particulate emissions. This has been one impetus for recovering energy in the form of RDF, rather than steam, for co-firing in an existing coal boiler (costly conversion is required to fire RDF in an oil- or gas-fired boiler). But air quality regulations have also discouraged the use of coal in urban areas, and have thus reduced the potential market for RDF co-firing with coal, particularly in the northeast.

Both of the mass-burning incinerators visited have experienced problems in complying with air quality standards even though they are equipped with electrostatic precipitators, and at Braintee these problems were quite costly. At Milwaukee, air quality restrictions on the utility purchasing RDF appear to have affected recovery indirectly. And at Monmouth County, air quality regulations may have been a factor in the failure to find a buyer for RDF.

Similar restrictions on the disposal of ash and residue have led to added costs and loss of revenue at Braintree and Harrisburg, although the North Little Rock incinerator has disposed of its ash and residue without problems. The other facilities are largely unaffected, since they do not involve incineration.

Finally, impediments that might tend to increase operating costs because of the use of new technologies, such as shortage of skilled labor, limited availability of spare parts, and limited operating experience with certain types of equipment, have had minor effects on operations at some facilities, but for the most part these problems are not discernibly different from those one would expect to encounter in almost any new high technology industry.

Limited Markets for Available Products

The point was made earlier that resource recovery facilities tend to be price takers in markets for recovered products. Hence, most of the effects of impediments which limit markets for available recovered products will take the form of reduced market prices. These effects may be felt in two ways in actual operating experience: revenues from the sale of recovered products may be less than would otherwise be the case; or recovery of a particular product may be abandoned altogether because prices are less than the marginal cost of

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recovery. It is not always possible to quantify or even observe these effects from data on supply-side operating experience alone, and it was beyond the scope of this study to investigate in detail the full extent of market demand at every location visited. Instead, some loss of revenue from products actually sold was inferred in cases where an impediment was known to exist in the economy at large, and instances were also identified where a product was abandoned specifically because of an impediment.

Energy Recovery—

Six of the facilities visited recover energy from waste in some form (steam, RDF, or methane), and the two shredding facilities were designed with the possibility of energy recovery from RDF in mind. One potential impediment affecting revenues from recovered energy is regulation of oil and gas prices. In the Appendix it is argued that the average price of natural gas and refined petroleum products is reduced by existing U.S. price controls. Thus, at the three facilities which sell steam, where price is based on the average price of oil, price controls reduce their revenues. At the facility which produces methane, price controls are less of a problem because the product customer owns the facility, and it can be argued that the value of the gas is the marginal cost of gas from other unregulated sources. The two facilities which produce RDF receive revenues based on the average price of coal. Regulation of domestic oil and gas prices can affect the price of coal, although the actual effect does not appear to have been large. Thus oil and gas price controls had some negative impact at three facilities -- the three steam producers -- but little or no impact at the others.

Another impediment which might be expected to affect energy recovery, franchise restrictions on steam and electric sales, was not observed to affect any of the facilities visited.

Rate regulation of electric utilities is thought to limit the extent to which utilities might be customers for energy recovered from resource recovery plants. Allowance of a fixed rate of return on invested capital is thought to discourage utilities from undertaking risky investments (such as boiler conversion to fire RDF); and fuel adjustment clauses which allow utilities to pass along fuel costs are thought to reduce the incentive for fuel cost savings through the purchase of RDF or steam generated from refuse. Nonetheless, at four of the sites visited, utilities were actively involved in one form or another: at Harrisburg, Pennsylvania Power and Light now buys all the steam the plant can supply in the winter, with lower purchases during the summer months; at Ames and Milwaukee, the municipal electric utility and Wisconsin Electric Power Company, respectively, buy RDF from the resource recovery plants, although Milwaukee can supply more RDF than WEPCO is willing to buy; and at Mountain View, Pacific Gas and Electric actually owns and operates the landfill gas recovery facility. At Braintree and North Little Rock, steam sales are being made to private companies and additional steam could be sold if a buyer could be found. At Monmouth and New Castle Counties, no RDF customers have been found, although in the latter case the local utility expressed a willingness to conduct a test burn. Evidence that rate regulation of utilities is an impediment to resource recovery is thus ambiguous.

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Materials Recovery—

Most impediments to resource recovery which are thought to limit markets for available products affect markets for recovered materials such as ferrous metal, aluminum, glass, and paper, rather than energy. Although seven of the eight facilities visited have undertaken some form of materials recovery, actual and expected revenues from recovered materials are small compared to revenues from energy recovery or to savings in landfill operations (at locations where shredding is done). To the extent that tax subsidies for virgin materials affect the market price for recovered materials, however, revenues from recovered materials are probably somewhat less than might otherwise be expected. This is particularly true for ferrous metals, the most common form of recovered material. Where aluminum recovery is practiced, it is done through hand-picking bulk items; recovery of aluminum cans is either not feasible because of the process used (e.g., mass incineration) or has been unsuccessful for technological rather than marketing reasons. Lack of product standards led to abandonment of a product line in two instances at New Castle County, and restrictions on use of ash or residue curtailed plans for marketing certain products there and at two other facilities.

Siting restrictions were found to be an actual impediment in only one instance, although it should be noted that locational considerations are often important when a recovered product is costly to transport (e.g., steam). Siting restrictions in North Little Rock caused the city to abandon plans for locating incinerators at multiple locations, which would have reduced haul costs. The location finally chosen for the single facility was largely dictated by the location of a steam customer. Similarly, customer location has affected operations at the other two incineration facilities in the sample, although siting problems were not an impediment in the same sense. Comparing these two facilities, it is significant that in Harrisburg the presence of a district heating system provides a market for all the steam available, albeit at some distance from the incinerator, while in Braintree more steam is available than can be used by the small industrial user, and district heating is not feasible because of low-density land use. The presence of a gas transmission line on the Mountain View landfill was a factor in selecting this location for gas recovery. With RDF production, plant location seems to be influenced more by disposal markets -- plants are centrally located to minimize haul costs of collection vehicles. At Ames the RDF customer is located in close proximity to the plant, but landfilled residue is hauled several miles; at Milwaukee both RDF and residue are transported to distant locations; and at the two shredding facilities unimplemented schemes to produce RDF envisioned hauling RDF to distant points from plants located at landfills.

WHAT CHANGES WOULD MAKE RESOURCE RECOVERY ECONOMICAL?

This section summarizes some sample calculations that illustrate the sensitivity of the financial positions of the facilities visited to changes in various parameters. It should be stressed that the calculations represent order of magnitude estimates and do not take into account a variety of factors that would be considered in a more detailed study of the facilities. The

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sensitivity analysis is conducted with respect to financial results projected for 1979 as presented in Table 3.

Increases in Throughput

One question of interest is the level of throughput that would be required for breakeven operation. The Mountain View facility is expected to be profitable in 1980; the rate of landfill gas extraction there could be reduced by up to 33 percent and still result in breakeven operations. At Harrisburg, throughput would have to be increased by 14 to 35 percent (using upper- and lower-bound estimates for operating costs) over 1979 to achieve breakeven results, a prospect that does not appear unreasonable. At Ames, it appears at first glance that increasing throughput to plant capacity would not be sufficient to achieve breakeven results at current prices and costs, but this is largely because tipping fees are kept artificially below market prices. If tipping fees were comparable to fees at landfills in neighboring counties, throughput would have to be increased by 13 to 40 percent (upper and lower cost estimates) over 1979 to achieve breakeven results. The prospect of this is not as good as in Harrisburg, however, because the Ames facility has already captured the entire disposal market available to it. Increasing throughput at New Castle County would have ambiguous results. Profits of the plant operator are very sensitive to changes in the fraction of waste shredded, and depending on how operating costs vary with increased throughput, profits might increase or decrease; for the overall operation, the results are similarly unclear because the value of savings to the landfill operation that result from shredding cannot be readily estimated. At the other four facilities, no breakeven level exists for currently prevailing prices and costs. That is, even if throughput at these facilities were increased to plant capacity, increased revenues would not be sufficient to cover total variable and fixed costs. Breakeven operation could not be brought about by increases in throughput alone.

Increases in Rates of Recovery

A related question, particularly at plants producing RDF, is whether increases in the rate at which various products are produced from a given level of throughput would result in breakeven operation.

Ferrous Metal—

All of the facilities except Mountain View have the capability of recovering some quantity of ferrous metal. At the three incineration facilities this could be done either through hand-picking prior to incineration or through magnetic separation from incinerator ash. At North Little Rock a small amount of hand-picking has been done, at Harrisburg a small amount of magnetic separation has been done, and at Braintree neither has been attempted. In all three cases, increasing the rate of hand-picking or magnetic separation would make modest contributions to revenue, but not enough to overcome current operating deficits. At the two shredding facilities, magnetic separation and sale of ferrous metal to detinners at rates approaching 3 percent of waste shredded has been carried out in the past, but these activities have been severely curtailed because the buyers went bankrupt. Renewing this market would contribute moderately to profits of

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the New Castle County plant, but even if the market were renewed at the higher rate of 7 percent (the total amount of ferrous metal usually found in mixed waste), the added revenues would not overcome the current operating deficit in Monmouth County. Finally, the two RDF plants are currently recovering ferrous metal at the rates of between 5 and 6.5 percent of waste throughput. The revenues from recovering the remaining ferrous metal available in mixed waste would not make these operations profitable. Thus, while ferrous metal recovery can make a modest contribution to revenue when it is marketable, improved ferrous recovery and sales alone would not bring about breakeven operation.

Refuse-Derived Fuel--

The Ames facility has an RDF recovery rate of about 75 percent (per processed ton); the Milwaukee facility has a recovery rate of about 38 percent (per received ton). At Ames, increasing the RDF recovery rate is probably not possible without reducing the quality of fuel. At Milwaukee, increasing the RDF recovery rate to the plant design level of 60 percent would reduce the current operating deficit by about 27 percent if it could be sold. Thus, at current prices and throughput levels, improved RDF recovery by itself would not be sufficient to achieve breakeven operation at these two facilities.

Other Materials--

One reason for producing RDF instead of engaging in mass incineration is that it permits other materials, such as aluminum, glassy aggregate, and bundled paper to be extracted from the waste stream as well. Aluminum recovery was incorporated into the design of both the Milwaukee and Ames plants, but to date has not taken place on any sigificant scale. No sales of glassy aggregate or aluminum have occurred at either location; small quantities of bundled paper have been recovered at both locations. However, even if these materials were recovered at rates originally projected, they would not be sufficient to offset existing operating deficits at current prices.

Combinations of Changes--

Not specifically considered is the possibility that rates of recovery of several products could change simultaneously. However, it appears that while improved materials recovery may make modest contributions to revenue at recovery facilities, these are usually insufficient to make a facility profitable unless it is close to breakeven operation already.

Increases in Landfill Tipping Fees

Four of the facilities visited are in effective competition with landfills for solid waste disposal, and rough comparisons can be made with tipping fees in surrounding areas at two other facilities.

If the Harrisburg incinerator could increase its average disposal charge by $2.60 per ton, its projected 1979 deficit would be erased. An increase of this size could be sustained without losing customers to competing disposal providers if the latter were to increase their prices by the same dollar

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amount. This would represent price increases of 35 to 43 percent for these providers, which is within the range that might result from strict enforcement of RCRA. Thus, at Harrisburg, it apears that pricing of landfill disposal below full social cost may have been an impediment to economical resource recovery.

By similar argument it can be shown that landfill tipping fee increases of 79, 200, and 245 percent at Braintree, Monmouth County, and North Little Rock, respectively, would have allowed these facilities to erase their deficits and remain competitive. In the Appendix it is estimated that strict enforcement of RCRA could, under some conditions, raise landfill fees by as much as 88 percent. Thus an increase of 79 percent is high but not entirely unreasonable; furthermore, the Braintree facility enjoys a locational advantage which means that it could be competitive and profitable if RCRA-induced increases were somewhat less. It is unlikely, however, that RCRA enforcement would lead to landfill tipping fee increases of 200 percent or more.

The facilities at Ames and Milwaukee have contractual agreements to receive all waste from the municipalities they serve, and they do not receive waste from outside these areas. Thus they are not in direct competition with landfill disposal facilities. However, if landfill tipping fees in surrounding areas are representative of what landfill costs could be within their service areas, then landfill costs would have to rise by 42 percent in Ames and over 100 percent in Milwaukee in order for the recovery facilities to remain competitive. It is unlikely that landfill disposal would be this much more expensive in Ames since fairly strict landfill standards are already enforced throughout Iowa; and even with added hauling costs that would be incurred with landfill disposal in Milwaukee, it seems unlikely that the full social cost of landfill disposal would be twice the present nominal cost.

Increases in Oil and Coal Prices

The price of steam and RDF at five of the facilities visited is based on the price of equivalent amounts of oil or coal. The price of energy has been rising in recent years, and it is often hoped that if oil and coal prices rise faster than operating costs of recovery facilities, then these facilities will become profitable. Pricing structures vary widely among the facilities visited, but if operating costs and price structures remain as they were in 1979, then real energy prices would have to increase by the following amounts for these facilities to achieve breakeven operation from this change alone: 44 percent in Harrisburg, 59 to 85 percent in North Little Rock, 99 percent in Ames, 200 to 300 percent in Braintreee, and over 400 percent in Milwaukee.

Conversely, at Mountain View the marginal price of energy could fall by as much as 30 percent and still leave the facility profitable. In this case, deregulation of domestic gas prices could affect profitability, since it would probably lead to increased domestic prices and a consequent decrease in the price of imported gas, at least in the short run.

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Increases in Prices and Marketability for Recovered Materials

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Increased revenues from recovered materials, either from increased prices or selling greater quantities, or both, could help reduce operating deficits at some facilities. Revenues from recovered materials would have to increase by 200 to 250 percent at Milwaukee and 500 percent at Ames for the current deficits to be erased. At New Castle County a return of the ferrous scrap market at former production and price levels would increase the operator's profits and reduce the deficit for the overall operation. For the overall operation to break even, net revenues at 230 percent of their former level would be required.

Finally, some facilities have produced more energy than they could readily sell in recent years. The Monmouth County facility has not found a buyer for its potential RDF product; the North Little Rock facility produced excess supplies of steam until its closure, as does the Braintree facility; and the Milwaukee facility could probably supply additional buyers with RDF.

Combination of Changes

Not explicitly considered is the possibility that several factors could change simultaneously. A change in any one factor outlined above can rarely be expected to make a facility economically viable, and some facilities would not be affected by changes in a single factor. The results described here are presented in summary form in Table 9. In some cases (increases in plant efficiency and throughput, strict RCRA enforcement), estimates are given of the changes that might reasonably be expected. It is beyond the scope of this report to speculate on how operating costs or commodity prices may change in the future.

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TABLE 9. CHANGES THAT WOULD BE REQUIRED FOR BREAKEVEN OPERATION

Facility	Throughput	Ferrous recovery	RDF recovery	Landfill prices	Energy prices	Materials prices	Added markets
Harrisburg, PA	14-35%	>capacity	nm	35-43%	44%	-	-
Braintree, MA	>capacity	-	nm	79%	200-300%	-	steam
North Little Rock, AR	>capacity	>capacity	nm	245%	59-85%	-	-
Monmouth County, NJ	>capacity	>capacity	nm	200%	nm	-	RDF
New Castle County, DE	nm	ambiguous	nm	nm	nm	230%	various
Ames, IA	13-40%	>capacity	>capacity	42%	99%	500%	glass
Milwaukee, WI	>capacity	>capacity	>capacity	>100%	>400%	200-250%	RDF
Mountain View, CA	-33%	nm	nm	-14%	-30%	nm	-

Note: Negative entries indicate that conditions could decline by the indicated amount and the operation would still be at a breakeven level.

nm = Not meaningful.

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SECTION 3

HARRISBURG, PENNSYLVANIA

SUMMARY

The City of Harrisburg, Pennsylvania, owns and operates a mass-burning waterwall incinerator with a capacity of 720 tons per day (tpd). The incinerator processes all municipal solid waste collected in the city as well as some waste from surrounding communities. Recently it has begun to produce steam for use in a district heating system owned and operated by Pennsylvania Power and Light Co. (PP&L). Competition from landfill disposal and overestimates of the waste volumes available from within the city have resulted in operation of the facility at well below capacity. However, throughput of waste is increasing and the facility may prove economical in the near future.

BACKGROUND

Area Characteristics

Harrisburg is located in south-central Pennsylvania 100 miles west of Philadelphia in an industrial region on the Susquehanna River. It is the capital of Pennsylvania and the county seat of Dauphin County. The city had a 1970 population of 68,000 within a county of 224,000 and an SMSA of 411,000. Since the 1950's the city's population has been decreasing and was estimated to be about 58,000 in 1975. As both the state capital and a county seat, Harrisburg's employment base is dominated by the government sector (32 percent in 1970). Wholesale and retail trade (19 percent), services (16 percent) and manufacturing (15 percent) account for most of the remaining employment.

Historical Methods for Solid Waste Disposal [1,K]

Prior to construction of the present facility, Harrisburg disposed of garbage at a local swine farm and disposed of other municipal solid waste at either a municipal incinerator or a municipal landfill on the northern boundary of the city. Surrounding communities used public and private landfills for waste disposal. The municipal incinerator, constructed in the 1920's, consisted of four units with a rated capacity of two tons per hour (tph) each, and burned about 40 tpd of mainly paper and cardboard from governmental and other offices. The landfill was opened around 1930 and had developed problems with rodent infestation and frequent fires. By 1966 the landfill was expected to reach capacity within three to five years and had

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been ordered to close by the State Department of Environmental Resources. An extensive search failed to locate any satisfactory site for a new landfill within a reasonable hauling distance. The area is geologically unsuited to landfill disposal because the limestone base results in leaching into groundwater unless expensive site preparation, including installation of plastic liners, is carried out.

Initial Planning for the Facility [1,10]

An engineering report authorized by the City Council in March 1966 and completed in January 1967 recommended construction of an incineration facility with two 300-tpd units at an estimated cost of $6.85 million. Neighboring towns in Dauphin County were invited to participate in preparation of the report with the hope that a regional disposal operation would result; this regional approach was dropped when only one borough accepted the invitation and others either expressed no interest or declined to participate. However, the capacity of the facility is more than sufficient for disposal of the city's waste. In recommending incineration, the report concluded that incineration would be relatively nuisance-free, sanitary, and require less land than either landfilling or composting, the alternatives considered. It also cited recent advances in technology, particularly experience with waste incineration in Chicago, to conclude that waterwall incineration would be economically feasible.

Initial estimates in the 1967 report were that annual operating costs for the facility would amount to $690,000, but that if the heat could be sold it would bring revenues of $157,000 annually, for a net operating cost of $533,000. Accurate records of refuse quantities had not previously been kept, but an attempt was made in June 1966 to measure quantities of waste being disposed by the city. These measurements indicated that the average quantity of refuse requiring disposal by the city was 300 tpd (five collection days per week). The city's population at that time was about 73,000, indicating a per capita waste generation rate of almost 6 pounds per day; estimates in later reports have been somewhat lower. The report went on to project an increase in population (contrary to historical trends), per capita waste generation, and heat content of waste in recommending a plant capable of handling 500 tpd of 6000 Btu/lb waste by 1995. The city recommended that capacity be increased to 600 tpd of 6000 Btu/lb waste in order to provide for future use by surrounding communities. This latter estimate was equated to a plant size of 720 tpd burning 5000 Btu/lb waste.

FINANCING AND CONSTRUCTION OF THE FACILITY [1,8,10]

Pennsylvania communities make frequent use of the public authority as a vehicle for financing waste treatment facilities as well as other single-use facilities such as parking lots and hospitals. Under this arrangement a paper organization is set up (in this case the Harrisburg Incinerator Authority) which is able to borrow independently of the legal debt ceiling imposed on municipalities. The Harrisburg Incinerator Authority was thus able to issue bonds and lease the facility to the city, which manages the facility and the debt, without having to obtain voter approval. Although the bonds were not

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backed by the full faith and credit of the city, the lease agreement required the city to adjust fees to meet payments and was treated in the market as a general obligation bond.

When land was acquired for siting the incinerator, located within the city limits some three miles from the city center near the river, sufficient space was available for constructing a new vehicle maintenance and storage center as part of the project. In December 1968, bids were received for the project totaling $9,484,155, of which $8,271,000 was related to the incineration facility.* In December 1969, the Incinerator Authority sold a 30-year "revenue" bond issue at an average interest rate of 6.50 percent for a principal amount of $12.5 million, which covered construction cost of $9.5 million and other costs including land acquisition, engineering and financing of $3 million. The delay of a year was partly due to lawsuits filed by local residents opposing the location of the facility and by unsuccessful equipment manufacturers objecting to bidding and selection procedures. Construction began in early 1970 and was completed in August 1972. Performance tests were conducted in May 1973, following a shakedown period, and the plant has been in continuous operation since then.

OPERATION OF THE FACILITY

Operation of the facility is under the direction of the Harrisburg Department of Public Works, which also includes a Sanitation Department responsible for collection of all residential waste in the city. The Sanitation Department operates a fleet of 12 trucks which collects waste five days a week. Most other municipalities in the area have collection arrangements with private haulers for residential waste, and all commercial and industrial waste is collected by private haulers. A city ordinance requires all waste produced in the city to be delivered to the Harrisburg incinerator, and additional waste is accepted but may also be taken to landfills.

System Description [1,6,8,K]

Collection vehicles deliver waste to a fully enclosed tipping floor after being weighed on an electronic scale which is integrated with the billing system. From tipping bays waste is dumped into a 5000-cubic-yard capacity storage pit, holding up to 1500 tons of waste. This is sufficient to feed the incinerator for 40 hours, and an additional 1000 tons can be stored on the tipping floor if necessary, so there is never a shortage of waste for firing over long weekends. This also allows waste to be received for several days while boilers are down without redirecting it to landfill.

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* The remainder was for construction of an unrelated vehicle center.

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Two traveling bridge cranes with 3-cy, 5.5-ton grapples feed waste from the storage pit into the two furnace charging hoppers at a rate of one charge every 4 to 5 minutes. A ceiling air intake above the pit develops a .25-inch negative pressure for dust and odor control and feeds air into the combustion chambers, supplementing a 300-hp force fan and a 100 hp overfire fan in each chamber.

A 2000-hp, 10-ton steam turbine hammermill shredder at one end of the storage pit receives bulky waste and tires from tipping floor level, shreds to 6-inch particle size, and conveys shredded waste to the storage pit for burning with other refuse, thus increasing ferrous metal content of the residue by as much as 20 percent. The two incinerator units are equipped with Martin reverse reciprocating grate stokers which discharge the residue into a water bath. The residue is then passed under a belt magnet for removal of ferrous metal and stored on site at the rear of the facility.

Each incinerator can generate steam with a peak capacity of 120,000 lb/hr, although peak efficiency has been found to occur at 90-92,500 lb/hr so each unit tends to be operated at this lower level. This represents a heat recovery rate of about 3 lb of steam per pound of refuse. The plant uses about 60 klb/hr of steam internally,* so at peak efficiency gross production is about 180 klb/hr, of which 120 klb/hr is available for export. It is estimated that addition of a third incinerator unit would add 70-75 klb/hr to export capacity. Feed water enters at 220°F and superheated head steam is produced at 260-280 pounds per square inch gauge (psig), 350-400°F.

Exhaust gases from the boilers enter electrostatic precipitators at about 420°F and are discharged from the precipitators to a 150-foot chimney. Auxilliary oil-fired burners capable of producing a total of 120 klb/hr steam may be operated during interruption of the waste stream flow. A 100,000-gallon tank of fuel oil stored on site is sufficient to operate the burners at this rate for 84 hours.

Original estimates were that each incinerator would operate continuously at 85 percent of rated capacity (to allow for minor outages) of 360 tpd for 330 days per year. Thirty-five days per year were thus planned for major repairs and maintenance. Total throughput during normal operation was thus expected to be 200,000 tpy. An interim throughput at a lower level was expected during an initial period while waste delivery and operating skills were developed, based on continuous operation at 70 percent of rated capacity.

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* 30 klb/hr for the shredder turbine, and 30 klb/hr for the boiler systems and plant heat.

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Steam Sales [5,8,K]

Initial cost estimates were made in the absence of a prospective market for steam. At one time consideration was given to providing steam heat to two public housing projects located about a quarter of a mile from the plant which are centrally heated by an oil-fired furnace. The failure of this scheme is attributed to lack of coordination between the Public Works Department and the Housing Department in Harrisburg. A steam buyer was eventually identified, however, in the Pennsylvania Power & Light Company (PP&L), an investor-owned utility which operates a district heating system in central Harrisburg. A 2.25-mile steam line was built by the city in 1978 to transport steam from the recovery plant to the PP&L plant, and steam sales began in December 1978.

Steam generation at the PP&L plant had been accomplished with four oil-fired boilers with a total capacity of 575 klb/hr of 150 psig steam at 390°. Demand for steam varies from 40 klb/hr in summer to 400 klb/hr in extreme cold weather. A 1975 study estimated that the incinerator would be able to supply an average of 48,000 lb/hr from October to May and 40,000 lb/hr during the remaining months each year if it processed an average waste quantity of 370 tpd. At a price of $4/klb, revenue from steam sales was estimated at $1,587,800. With the incinerator operating at capacity, it was estimated that 129 klb/hr would be available for export; the report recommended construction of a 14-inch steam line, which would be sufficient to deliver this quantity with a maximum line loss of 50 psig and 50°F. Construction cost for the steam line was estimated at $2,334,400, and annual operating and maintenance cost at $7,500. Assuming financing through a bond issue of $3.15 million at 5.5 percent over ten years, total annual costs were estimated at $425,400, for an annual net profit of $1,162,400.

The steam line was financed through the issue of general obligation bonds in November 1977 which were used simultaneously to refinance the 1969 bonds for the incinerator. The 1977 bond prospectus pointed out that the original project had not been self supporting and cited three reasons for this: delays in construction due to strike action and a flood during 1972; an initial tipping fee which was too low; and the failure to receive anticipated quantities of waste due to competition from neighboring landfills and due to having overestimated the quantity of waste that would actually become available. The total cost of refinancing the 1969 bonds was $13,441,720.70, the cost of the steam line and other improvements was $6,152,600, and other financing costs came to $2,140,679.30. A grant from the U.S. Economic Development Administration paid $1.1 million of the cost of the steam line, a short-term special obligation bond issue of $1.38 million covered part of the remainder, and the major bond issue of $19,255,000 over 22 years at approximately 5.6 percent funded the rest.

The agreement between PP&L and the incinerator requires that the incinerator deliver a minimum of 20,000 lb/hr either from the incinerator itself or from its auxiliary oil burners. Generally the auxiliaries should be necessary only during a system outage. The recovery plant has an export capacity of 120,000 lb/hr and produced an average of 74,000 lb/hr (8760 hr/yr)

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in 1978, about half of which would have been exportable had the sales agreement been in effect.

FINANCIAL ANALYSIS

Sources of Revenue

Revenues for the recovery operation are derived from three sources: disposal fees paid by waste haulers, sales of steam to PP&L, and sales of recovered ferrous metal. In the past, revenues have been insufficient to cover all expenses including debt repayment. The deficit is made up by a quarterly fee levied on Harrisburg property owners.

Disposal Fees— [4,K]

One-time haulers are charged $18.00/ton, with a minimum charge of $4.50. All other haulers are required to purchase an annual permit for $120, which is credited toward tipping fees charged to them. The basic tipping fee has been $12.80/ton for several years, with higher rates for bulky oversize waste, industrial waste and other items requiring special handling.

Recent changes have been made in the rate structure in order to attract additional customers. In January 1976 a rate of $11.80/ton was introduced for haulers delivering an average of over 1000 tons every four weeks; in March 1978 this quantity discount was further revised to $11.80/ton for over 850 tons in four weeks and $10.80/ton for over 1380 tons in four weeks. These charges were introduced in order to make the incinerator more competitive with a neighboring landfill and transfer station. The landfill, which is located about five miles from Harrisburg in Lower Paxton, charges about $1.50/cy ($4.50 to $7.50/ton). The transfer station is at about the same distance on the other side of the river in East Pennsboro and charges a fee of about $7.50/ton. Waste brought to the transfer station is then transferred to a landfill in York County.

In practice only three haulers, including the city Sanitation Department, qualify for the quantity discounts on tipping fees, but these three collect the majority of waste delivered to the incinerator. For example, during the 50-week period ending March 7, 1979, the City of Harrisburg Sanitation Department delivered 24,000 tons, while the two largest private haulers, United Disposal and Truman Horner, delivered 36,000 tons and 29,000 tons, respectively. These three accounted for 70 percent of the total waste delivered during this period.

Steam Sales— [9]

Revenues from steam sales are based on the value of fuel (oil) savings to PP&L from using incinerator steam plus the value of water saved by not buying water from the city. PP&L pays the city a percentage of its net cost savings at a declining block rate starting at 90 percent of the first $200,000 in annual savings and going down to 65 percent of any annual savings over $800,000. As an example, in December 1978, PP&L determined that its average oil cost was $.3071/gallon and, taking into account its plant efficiency (.81), estimated the fuel cost savings to be $3.05 per 1000 lb of steam

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received. Water cost savings represented another \$.05 per 1000 lb. Since this was the only steam delivered during the year, the city received (.9)(3.05 + .05) = \$2.79 per 1000 lb of steam delivered.

The existing arrangement for steam sales works to PP&L's advantage in at least two respects. First, PP&L is obligated to pay only a declining fraction of the fuel cost savings rather than the full amount. Second, the oil price used in the calculation of savings is an average inventory price rather than the utility's marginal (incremental) price. It can be argued that the utility should use the price of oil from its most recent purchase as an estimate of the price it would otherwise have had to pay for the oil saved. Because the price of oil is rising, this marginal price is likely to be higher than the average inventory price. The advantageous arrangement is a result of the utility having been up to now the incinerator's only potential steam customer. This will change in the near future, however, when the incinerator begins piping steam to the Sewer Authority next door for sludge drying and receives, in turn, dry sludge as fuel for the incinerator.

Quarterly Fees— [2,K]

The lease arrangement between the Incinerator Authority and the city requires the city to make up any deficit incurred by the Authority. This is done by levying a disposal fee on property owners in Harrisburg which is billed quarterly along with charges for water and sewerage. When introduced in January 1971, the quarterly fee was \$5.00 per unit for residential properties with up to four units. After the incinerator was refinanced this was increased to \$7.50 per unit in April 1978. Apartment buildings and others with more than four units are charged a reduced amount per unit. The disposal charge is in addition to the quartely collection charge levied on occupiers of residential units. The collection charge was \$4.50 per unit from January 1969 to April 1974, when it was increased to \$7.50; since April 1977 it has been \$10.00. Non-residential units whose waste is collected by private haulers may deduct the cost of private collection from the collection fee; thus every residential or non-residential unit occupier must pay a minimum of \$17.50 per quarter for solid waste service, including at least \$7.50 paid to the city.

A survey of residential collection routes in Harrisburg at various dates in 1978 indicated that residential customers presented an average of 56.8 lb/wk of waste for collection, or about 1.5 tons/yr. Since the residential collection charge of \$40.00 per year, or \$26.67 per ton, includes the disposal tipping fee of \$10.80 per ton, households pay \$15.87 per ton for collection service, or \$23.80 per year, and \$30.80 per ton for disposal or \$46.20 per year. The total cost to households of \$70 per year for solid waste service is considerably higher than in other municipalities in Dauphin County, but collection service is probably less expensive. Residents in municipalities with private haulers pay from \$36 to \$66 per year for waste service, and average \$53; residents in municipalities with contract service pay from \$32 to \$66 per year and average \$48.

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Statements of Income

A number of factors make it difficult to construct income statements for the incinerator on a consistent basis. The two most important factors are a change in the city's accounting system for the incinerator between 1975 and 1976 and the refinancing of the incinerator as part of the bond issue of 1977. The figures shown in subsequent pages represent our best judgment as to the incinerator's financial history.

Conventional Analysis— [3,6,K]

Table 10 provides a summary of the operating results for the incinerator for the years 1974 to 1978 and an estimate for the year 1979. The revenue figures include the disposal fees charged to waste haulers, including city trucks, but do not include the quarterly fee assessed against Harrisburg property owners. The latter is shown under "Other revenues." The expenditure category "Debt service" represents actual disbursements to bondholders.

An overview of Table 10 reveals that disposal fees have been the dominant source of income throughout the period with steam revenues expected to become a major revenue source beginning in 1979. Throughput and thus disposal fees have varied substantially and have been well below the anticipated level of 200,000 tons/yr. Since the beginning of operations in mid-1973, the incinerator has consistently operated at a loss. Revenues have been sufficient to cover all variable costs but only a portion of the annual payment of interest and principal. However, the incinerator may come very close to breakeven operation in 1979 as a result of the projected revenue from steam sales to PP&L.

Of particular interest is the bottom line in Table 10, which shows the per ton net cost of disposal. The net cost of disposal can be defined as total operating expenditures, less revenues from the sale of scrap or steam. As can be seen, the per ton cost of disposal has varied between about $14 and $20. This is about two to three times the price charged by the landfilll and the transfer station which are located a few miles outside of Harrisburg. Note also, however, the large decline in per ton cost projected to occur in 1979 as a result of the new revenue contribution from steam sales.

The incinerator's financial picture is made somewhat more attractive by two trends operating in its favor. First, fuel prices and thus steam revenues are likely to increase faster than the general rate of inflation and the rate of increase in other incinerator expenses. Thus the current surplus of revenues in comparison with variable expenses is likely to grow. Second, the annual expense for debt repayment and interest should remain stable at between $1,350,000 and $1,400,000 for the next several years. Thus the growing surplus could gradually catch up with the fixed debt and interest payment. If one assumes, for example, that in 1980 and beyond steam revenues grow at 10 percent per year, interest and principal remain fixed, and all other revenues and expenses grow at 6 percent per year, the incinerator could show an accounting profit in 1982 or 1983.

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TABLE 10. OPERATING DATA, HARRISBURG, PENNSYLVANIA INCINERATOR PLANT
(All dollar amounts in thousands of dollars, except per ton amounts)

	1974	1975	1976	1977	1978	1979[1]
Operating revenues						
Tipping fees & permits	1319	1913	1848	1175	1424	
Less refunds	0	78	24	2	1	
Net tipping fees & permits	1319	1835	1824	1173	1423	1600
Sale of scrap	5	12	27	8	6	
Sale of steam	0	0	0	0	86	1000
Total operating revenue	1324	1847	1851	1181	1515	2600
Operating expenditures						
Supplies & services	522	655	658	849	643	
Less refunds	0	32	13	0	0	
Sub-total	522	623	645	849	643	1000
Wages, salaries & fringes	487	523	536	441	522	600
Debt service	878	877	875	375[2]	1057	1364
Total operating expenditures	1887	2023	2056	1665	2252	2964
Operating profit (loss)	(563)	(176)	(205)	(485)	(737)	(364)
Net disposal cost[3]	1882	2011	2029	1658	2160	1964
Other revenues						
Quarterly fees	na	209	200	271	200	250
Interest	3	1	22	14	20	
Other	10	1	1	60	78	
Other expenditures						
Interest	32	0	na	na	na	
Other	0	95	na	na	na	
Refuse processed (10^3 tons)	96	149	129	96	125	140
Steam produced (10^6 lbs)	571	na	na	542	602	660
Steam sold (10^6 lbs)	0	0	0	0	31	420
Operating revenue per ton	13.79	12.40	14.35	12.30	12.12	18.57
Operating cost per ton	19.66	13.58	15.94	17.35	18.02	21.17
Operating profit (loss) per ton	(5.87)	(1.18)	(1.59)	(5.05)	(5.90)	(2.60)
Net disposal cost per ton[3]	19.60	13.50	15.73	17.27	17.28	14.03

1. Figures for 1979 are projections by Mathtech staff.

2. $992,000 was budgeted for principal and interest payments on debt in 1977, but expenditure was $376,000. The reduction apparently resulted from the manner in which the debt was refinanced.

3. The net cost of disposal is taken to be total operating expenditures less revenues from the sale of scrap or steam.

na = Not available.

Sources: Harrisburg Office of Finance and Harrisburg Incinerator Authority. Revenues are actual or estimated actual (based on nine months) figures from budgets of succeeding years, except for tipping fees, which are actual figures from billing records. Expenditures are from annual summaries of computerized cost accounting records.

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Replacement Cost Analysis--

A somewhat different view of the situation is provided when the income statement is recast with the facility shown at its replacement cost rather than in terms of its historical cost. An income statement using replacement cost would be indicative of the incinerator's financial position if the facility were constructed in the current year. Hence, the replacement cost income statement is the one which other cities should look at if they are in the process of considering a resource recovery project. In general, if construction costs have escalated at a faster rate than other revenue and expense categories since the original construction period, then the financial picture will appear worse compared to the historical cost basis. If construction costs have escalated at a slower rate, then the financial picture will appear better than the historical cost income statement.

Our best estimate is that the replacement cost for the facility, including the steam line and land, would be about $28.1 million. This figure was obtained by escalating the basic facility cost of $10.9 million* in 1969 and the steam line cost of $3.2 million in 1977 to the current year 1979 using the Handy-Whitman index of utility construction costs. Assuming that this amount would again be amortized over 30 years but that an interest rate of 7 percent would now be required, the annual cost would be $2.26 million. When this figure is used in the estimated income statement for 1979, a net loss of $1.26 million or $9.00 per ton is obtained. The corresponding net cost of disposal also increases to $2.86 million, or $20.42 per ton. These figures are larger than those shown in Table 10 because construction costs have risen more rapidly than the general price level and because interest rates are higher. In effect, this means that if Harrisburg were going to invest in resource recovery, it is better to have done so when it did rather than to have waited until 1979.

COMPARISON OF PLANNED VS. ACTUAL RESULTS

Harrisburg's experience with the incineration project has differed from its expectations in several respects. These differences are summarized briefly below. We should stress that in making these comparisons our intention is simply to identify past problem areas so as to improve future decisionmaking about resource recovery.

Waste Availability

The facility has operated at well below design capacity (200,000 tpy) due to lower than expected deliveries of waste (130,000 tpy). The problem has been smaller waste volumes from the city itself, rather than from surrounding areas, because deliveries from the latter have actually exceeded expectations. These circumstances are summarized below.

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* This excludes the cost of the unrelated vehicle center and a proportionate share of engineering and financing costs.

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Waste From Within the City— [1,2]

The volume of waste requiring disposal by the city was estimated in 1966 to be 300 tpd for a five-day week (78,000 tpy). This figure was projected to increase to 500 tpd by 1995 in response to both population increase and increased per capita waste volumes. In fact, however, solid waste collections within Harrisburg appear to have declined. In 1977, for example, the total solid waste collected in Harrisburg was estimated to be only 55,000 tpy, including industrial and demolition waste which is not usually taken to the incinerator.

Much of the apparent reduction can be attributed to the population decline within the city. Between 1966 and 1977, the city's population fell by about 24 percent, contrary to the original expectations that population would increase. It is also possible that the waste volumes in 1966 were overestimated. The 1966 estimate was based on measurements made in June of that year and June is a month with generally higher than average waste collection. Also, if the 1966 estimate is taken at face value, then it would suggest that per capita waste collection has also declined since 1966, again contrary to expectations.*

Waste From Outside the City— [1,2]

In the initial planning stages of the project the city was unsuccessful in its attempts to obtain the support and participation of neighboring communities. The city did, however, increase the design capacity of the incinerator by 20 percent (100 tpd of 6000 Btu/lb waste or 120 tpd of 5000 Btu/lb waste) under the assumption that other communities would eventually participate. If we assume that the city has accounted for about 50,000-60,000 tpy of the deliveries to the incinerator (see the preceding section), then deliveries from outside the city have averaged 57,500-67,500 tpy between 1974 and 1977. This represents 221-260 tpd (5 days/wk) from outside the city, which is far superior to original expectations. Clearly then the low level of throughput has been due to the overestimate of waste volumes from within the city itself.

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* The per capita estimates for 1966 and 1977 are:

$$1966: \quad \frac{(78{,}000 \text{ tons}) \times (2000 \text{ lb/ton})}{(73{,}000 \text{ pop.}) \times (365 \text{ days})} = 5.9 \text{ lb/capita/day}$$

$$1977: \quad \frac{(55{,}000 \text{ tons}) \times (2000 \text{ lb/ton})}{(54{,}000 \text{ pop.}) \times (365 \text{ days})} = 5.6 \text{ lb/capita/day}$$

The probable variability in the samples upon which these estimates are based, however, is undoubtedly so large that the differences between years is not statistically significant.

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Cost of the Facility [1,10]

The consulting engineer had estimated (in 1967) that the project would cost $6,850,000 for a system consisting of two 300-tpd units. The actual bids for construction came in at $9,484,155, of which $8,271,000 was attributable to the incinerator and the remainder was for an unrelated vehicle center. Land acquisition, engineering and finance costs added about $3 million more to the cost of the project, of which about $2.6 million can be proportionally attributed to the incinerator. The total cost of the incinerator thus proved to be about $10.9 million, or 59 percent higher than original estimates. About one-third of the difference can be attributed to the expanded design capacity of the facility which at the city's request was increased by 20 percent to include two 360-tpd units. The remainder presumably represents the extent to which costs were simply underestimated.

Operating Problems [K]

The plant manager is generally pleased with the technical performance of the incineration plant, although some problems have arisen. The plant has an availability of about 80 percent on average.* Each stoker is shut down from 30 to 45 days per year for scheduled maintenance and an equivalent amount of downtime occurs for unscheduled maintenance. However, utilization has generally been closer to 60 percent because of insufficient waste input.

Fires and explosions in the storage pit are a hazard. Small fires which can be quickly extinguished occur several times a week in the pit. In April 1978 a much larger explosion occurred when 2800 gallons of paint thinner were illegally dumped. The resulting fire destroyed the overhead cranes and the shredder, and blew out a fire wall. This incident caused about $1 million in damage and shut down the plant for three weeks, during which time waste was redirected to a landfill.

Materials recovery has been far lower than originally projected. The magnetic ferrous separator was the last part of the plant to be completed and less attention was given to its operation. Only about 1 percent of the waste stream has been recovered as ferrous metal as compared with the 6 or 7 percent that is available; most of the recovered ferrous has been hand separated white goods sold to a scrap metal dealer for about $11/ton.

Residue from the plant has accumulated in a mound at the rear of the plant since its opening without being hauled to a landfill, and has been ordered removed. The residue has been approved for landfill cover when mixed with soil, however, and there are also plans to screen it for aggregate to be used for roadwork. One or both of these uses is expected to be a revenue source in the future.

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* In utility terminology, a piece of equipment is said to be "available" if it is capable of service, whether or not it is actually in use.

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There also seem to have been early problems with management of the facility, possibly due to local political changes. During the first few years of the plant's operation it was regarded as little more than a place to dispose of the city's waste; maintenance capabilities were limited, machinery deteriorated, and limited hours of operation discouraged some commercial haulers from delivering as much waste as they might have done. Since his appointment in early 1978, the present plant manager has expanded operating hours* and hired an on-site electrician, welder, pipefitter, and boilermaker to carry out routine maintenance. Another recent problem was a law requiring the Incinerator Authority to hire only Harrisburg residents. This was opposed by unions and was seen by management as a deterrent to attracting workers in skilled labor markets. A recent court decision declared the residency requirement a bargainable issue to be resolved by negotiation between the Authority and the unions, however.

Steam Sales [8,9]

The facility was built without a firm customer for steam although it was hoped that one could eventually be located. When a buyer was found in PP&L, the negotiated price for the steam proved to be considerably lower than had been hoped. In evaluating the proposed steam line between the incinerator and PP&L, the consulting engineer had assumed in 1975 that steam could be sold for $4 per 1000 pounds. In fact, however, the price received as recently as December 1978 was only $2.79 per 1000 pounds and may drop even lower during the course of the year because of the declining block rate structure of the steam tariff. Nonetheless, even at this lower price, the steam line should still prove to be a net moneymaker.

CONCLUSIONS

In this section we attempt to answer three questions: First, is the Harrisburg resource recovery operation economical? Second, if it is not, can this be attributed to the impediments catalogued in the Appendix? And third, what changes would be necessary to overcome these impediments?

Is the Facility Economical?

In the accounting sense of producing revenues in excess of costs, the Harrisburg Incinerator is not at present economical. The facility's revenues have been sufficient to cover all variable costs, but only part of the required annual payment of interest and principal. The remaining costs are paid for directly and indirectly by Harrisburg property owners.

Nor is the facility economical in the broader sense of providing the least costly disposal alternative. The net cost of disposal at the incinerator, including tipping fees and indirect subsidies, has been twice the

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* The waste processing schedule is now 24 hours per day, seven days per week. Waste deliveries are accepted 12 hours per day during the week, Saturday mornings, and by appointment at other times.

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rate charged by nearby landfill and transfer station facilities. The incinerator has also enjoyed the benefit of a requirement that all waste collected within Harrisburg must be taken to it. This imposes an additional indirect cost on Harrisburg residents since less costly disposal alternatives do exist.

There is some prospect that breakeven operation will be reached in the early 1980's. If oil prices continue to rise as they have, the facility's steam revenue from PP&L may outpace operating costs. In addition, new revenue sources are being developed from the sale of steam for sewage sludge drying, from the incineration of the dried sludge, and from the sale of residue for landfill cover or roadwork. However, speculation on whether these events will all occur, and whether any future savings will fully offset current losses, is beyond the scope of this study.

What Have Been the Impediments to Economical Operation?

Table 11 lists the various impediments to economical resource recovery catalogued in the Appendix, along with qualitative ratings of how each impediment has affected the experience at Harrisburg. The following discussion summarizes the results presented in the table.

In our judgment, much of Harrisburg's financial difficulty with the incinerator can be traced to having overestimated the quantity of waste that would be generated within the city, which led to building a facility whose economical operation required a larger throughput than was forthcoming. To some extent this difficulty has been lessened by attracting waste from outside the city. However, the additional deliveries from outside Harrisburg, over and above what was originally anticipated, have not been sufficient to offset the shortfall from within Harrisburg. The reason for this, in turn, is that land disposal alternatives are available to surrounding communities at a lower price than incineration. While we have no specific evidence that the low cost of these alternatives is related to the pricing of land disposal below full social cost, we suspect that this is the case and that strict enforcement of RCRA* provisions relating to landfills would eliminate much of the competitive advantage which the landfills now enjoy. If this is the case, then failure to price land disposal in the area at full social cost has been the most significant impediment to economical operation of the incinerator in the past.

Other impediments which probably have had some effect include: the fragmentation of local government which has limited the extent to which waste volumes from outside of Harrisburg could be directed to the facility (at present they are delivered voluntarily); equipment and design limitations which have in particular plagued the efficient recovery of ferrous scrap; difficulties in complying with air quality standards (for particulates) even

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* The Resource Conservation and Recovery Act of 1976.

TABLE 11. IMPEDIMENTS TO ECONOMICAL OPERATIONS (HARRISBURG, PA.)

Impediment	No effect evident	Some effect probable	Large effect probable
Restrict quantity or composition of waste			
Pricing of landfills below full social cost			x
Independent source-separation programs	x		
Returnables policy for bottles and cans	x		
Fragmentation of local government		x	
Restrictions on interstate movement of waste	x		
Seasonal or business cycle fluctuations	x		
Increase initial cost or restrict design			
Inadequacies of available technology		x	
High unit cost for equipment and parts	x		
Limited design experience		x	
Limitations on municipal financing	x		
Low first cost approach to public contracting	x		
Affect cost or efficiency of operations			
Limited operating experience	x		
Limited availability of spare parts	x		
Shortage of required labor skills including supervision	x		
State and federal regulation of air quality		x	
Restrictions on disposal of ash and residue		x	
Limit markets for available products			
Siting restrictions	x		
Franchise restrictions on steam and electric sales	x		
Tax subsidies for virgin materials		x	
Price controls on oil and gas		x	
Lack of futures markets for scrap	x		
Unpriced mining and processing costs	x		
Differential freight rates	x		
Lack of product standards for reclaimed materials	x		
Rate regulation of electric utilities	x		
Restrictions on use of ash, residue and shredded materials		x	
Product labeling restrictions	x		
Government procurement policies	x		

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though the design includes electrostatic precipitators; restrictions on uses for ash and residue which have only recently been lifted; and tax subsidies and price controls for oil which reduce oil prices and thus the price that can be obtained for waste-generated steam.

What Changes Would Make the Facility Economical?

To illustrate the sensitivity of the incinerator's income statement to various parameters, we carry out below some sample calculations. It should be stressed that the calculations represent order of magnitude estimates and do not take into account a variety of factors that would be considered in a more detailed study of the facility. The sensitivity analysis is conducted with respect to the financial results projected for 1979.

Increases in Throughput—

The first question of interest is the level of throughput required for breakeven operation. We can obtain an upper-bound estimate by making the assumption that all revenues and expenses, except interest and principal, are proportional to throughput. This allows one to develop the following algebraic expression for the incinerator's net profit:

$$\Pi = \frac{2600}{140} \cdot Q - \frac{1600}{140} \cdot Q - 1364$$

where Q is the refuse processed. Solving for the breakeven value of Q yields a throughput of 191,000 tons, or 35 percent higher than the projected 1979 level. This is an upper-bound estimate because the facility is likely to have declining average costs for throughput above 140,000 tons. A lower-bound estimate can be constructed by assuming that costs are unchanged for small increases in throughput above 140,000 tons. This leads to the profit equation

$$\Pi = \frac{2600}{140} \cdot Q - 1600 - 1364$$

and a breakeven throughput of 160,000 tons, or 14 percent higher than the projected 1979 level. The actual breakeven level is thus likely to be somewhere between 160,000 and 191,000 tons.

Increase in Landfill/Transfer Station Prices--

If the incinerator could increase its average disposal charge by \$2.60 per ton, its projected 1979 loss would be erased. An increase of this size could be sustained without losing customers to the competing landfill and transfer station if the latter were to increase their prices by the same dollar amount. In the case of the landfill this would represent an increase of about (100)(2.60/6.00) = 43 percent, and in the case of the transfer station an increase of about (100)(2.60/7.50) = 35 percent. Both percentage increases are within the range of changes that might occur with strict enforcement of RCRA (see Appendix).

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Increase in Oil Prices--

An increase in steam revenues of $364,000 would also erase the projected deficit for 1979. To achieve this increase without increasing the quantity of steam sold would require an increase in the price of steam and thus in the price of oil. If we assume that the projected 1979 steam revenues are based on oil at $.3071 per gallon (the price quoted by PP&L in December 1978), then the required increase in the price of oil turns out to be $.134 per gallon,* or a 44 percent increase. It is possible that PP&L's average oil price may increase by this amount given the increases that have occurred in imported oil prices since the beginning of the year.

Combinations of Changes--

We have not explicitly considered above the possibility that several factors could be changed simultaneously. It seems clear, however, that if landfill prices and oil prices both increased, for example, then the required increase in each case would be smaller than calculated above. And, in fact, this is the scenario that will most likely take place.

---

*

$$(\Delta p\ \$/\text{gal}) = \frac{(\$364{,}000)\ .\ (.3071\ \$/\text{gal})}{(.65\ \frac{\$\ \text{received}}{\$\ \text{saved}})\ .\ (\$3.05\ \$/\text{klb})\ .\ (420{,}000\ \text{klb})}$$

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ACKNOWLEDGMENTS

We are grateful to Mr. Jack Karper, Deputy Director of Public Works, City of Harrisburg, and Mr. M. Steckbeck of the Bureau of Finance, City of Harrisburg, who provided information and material in addition to the references cited above. Reference to information contributed by Mr. Karper and his staff during our interview is denoted by the letter "K" appearing in the text.

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SECTION 4

BRAINTREE, MASSACHUSETTS

SUMMARY

The town of Braintree, Massachusetts, owns and operates a mass-burning waterwall incinerator with a 240-ton-per-day (tpd) capacity. Difficulty in establishing regional cooperation with other municipalities, problems with meeting air pollution standards, and the absence of sufficient demand for steam which the incinerator produces have contributed to making the facility a very costly operation during its early years. Rewards for the town's technological and organizational efforts at innovation have thus been meager in the past, but rising landfill costs in the area are beginning to make the cost of incineration comparable to that of alternative disposal methods.

BACKGROUND

Area Characteristics

Braintree is a suburban community of about 40,000 located some 12 miles southeast of Boston along the Southeast Expressway, a major traffic artery. The town has experienced more gradual population growth during the 1960's and 1970's compared to the rapid growth of the 1950's. It has a representative town meeting form of government, common in Massachusetts, with administrative authority vested in a board of five selectmen. Although there are a small number of industrial facilities, most of the land use is low density residential.

Historical Methods for Solid Waste Disposal

Before 1966, Braintree disposed of municipal solid waste in a 31-acre open dump near the geographical center of the town adjacent to the expressway entrance. In that year, the Massachusetts Bay Transit Authority announced plans to extend the rapid transit system through Braintree. Because of the location of the dump, much of the land was required for a proposed rapid transit station and 2500-car parking garage. [7,9]

In the early 1960's, the town created a Refuse Committee to deal with solid waste problems. In 1966, the committee began to investigate alternative disposal systems in view of the impending closure of the dump. The committee appears to have proceeded along two lines. On one hand, it was asked to

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survey other communities to determine the feasibility of undertaking a joint or regional effort for either landfill or incineration. Simultaneously, an engineering consulting firm was engaged to design an incinerator to be located in Braintree on the site of the dump. In 1968, the committee reported that none of the local municipalities were willing to consider any form of firm commitments with Braintree. It concluded that since no town was willing to have another town's rubbish hauled through its streets and disposed within its boundaries, Braintree would have to solve its own problems. Since no land was available for landfill in the town, a decision was made to construct an incinerator. [3,7]

Initial Planning for the Facility

Surveys in 1966 of quantities of waste collected in Braintree and quantities disposed at the dump indicated that about 90 tpd originated in the town. This was projected to increase to 135 tpd over the 20-year life of the facility. Both figures were on the basis of a five-day week. Estimates of the capacity that would be required for a regional facility at the same location indicated that 350 tpd could be delivered in 1970, increasing to 510 tpd in 1990. [3]

The plant was designed to contain two separate boiler units with a capacity of 120 tpd each. Although the total plant capacity of 240 tpd was considerably more than required by Braintree, it was felt that this size and configuration would provide the town with capacity to burn all of its waste, even when one of the units was out of operation. It was hoped that waste could be attracted from other towns, despite the absence of firm commitments, to bring the facility closer to full capacity with both units operating. The plant design also allows for a third, 400-tpd unit to be added at a later date should the facility become a regional operation. [2,3,7]

It was apparently assumed from the beginning that the town would own and operate the incinerator facility. The town already owned and operated its own electricity generation and distribution systems as well as a water supply and distribution system. Hence, there was a considerable backlog of experience with utility systems. The Town Refuse Committee in fact recommended that the town's electric department be authorized to operate the incinerator. As it turned out, however, the incinerator has been operated independently of the electric department. [2]

Considerable attention was given to the problem of controlling fly ash emissions from the incinerator. Although no explicit state or federal air quality standards for incinerators existed at the time of the design (1967), the decision was made to incorporate electrostatic precipitators. Precipitators were then in use in several European facilities, but the decision was of some significance since at that time apparently no U.S. plants had electrostatic precipitators installed. [3]

Initial estimates were that the facility would cost $2.75 million to construct and involve about $169,000 per year in operating expenses. It was also estimated that steam could be sold to a nearby industrial facility for $160,000 per year. [7]

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FINANCING AND CONSTRUCTION OF THE FACILITY

In June 1968, the town sold an issue of $3,435,000 in general obligation bonds to finance the capital cost of the facility. The bond issue included $2.75 million for the incinerator, payable over 20 years, and $685,000 for other unrelated facilities (sewers and a golf course). The town's A-1 bond rating and an exemption from state and local taxes as well as federal income taxes enabled the bonds to attract a 4.4 percent rate of interest. [5,SC]

Contracts for construction of the incinerator were awarded to low bidders and totaled $2,595,000. The initial engineering studies had cost $200,000. Construction began immediately and was expected to be completed by May 1970. The plant began intermittent operation in March 1971, and began burning all refuse on a regular basis in May 1971, or about one year behind schedule. Official acceptance tests were passed in August 1971. [2,3]

OPERATION OF THE FACILITY

The plant is operated by the Waste Disposal Department, headed by the plant superintendent. When it opened it was operated for two eight-hour shifts five days a week, and was intended to burn gas during the third shift and on weekends. This schedule was later changed to two twelve-hour shifts five days a week, and then in March of 1979 to three eight-hour shifts five days a week, with the number of employees increasing from 14 to 22. [10,1,3] Beginning in July of 1979, the facility planned to operate 340 days per year on a three-shift basis. [1,3,9,SC]

Description of the Facility

External and cross-sectional views of the facility are provided in Figures 1 and 2. During normal plant operation, refuse trucks discharge waste through the openings of a roll-up door of the main building, which also contains administrative offices and showers, into a 1340 cubic yard storage pit. From the storage pit the waste is lifted by a bridge crane with a 3.5 cubic yard grapple bucket and fed into the charging chute. From there refuse falls onto the first of two traveling grate stokers. The first grate dries the waste with heat from the second burning grate, to which the waste then falls and burns at 406°F. Waste heat from the furnace fires the two waterwall boilers which can each produce up to 30,000 lb/hr of 250 psig saturated steam. [3,6,9,SC]

Economizers are used to preheat the boiler feedwater in order to increase efficiency. The plant efficiency is estimated to be 82 percent when burning normal waste. With both boilers operating, 60,000 lb/hr of steam is produced at a firing rate of 225 tpd of waste, or 6400 lb of steam per ton of waste. Excess steam not used internally or shipped to a nearby leather factory is condensed and vented. [3,SC]

Residue from incineration is less than one-seventh the volume of incoming waste, and about one-quarter of its weight. The residue is about 18 percent

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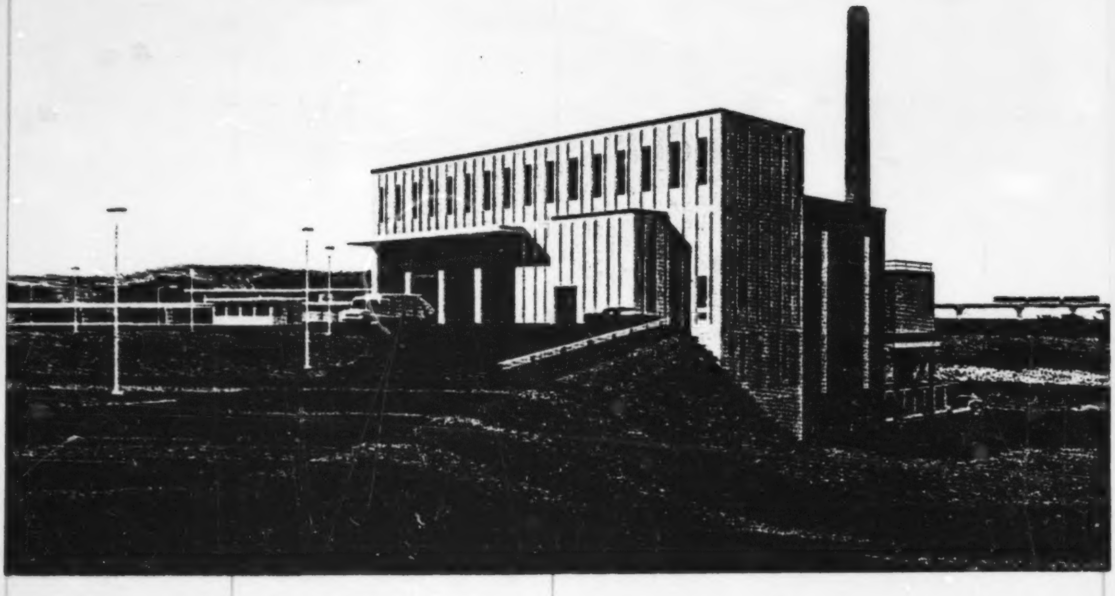

Figure 1. External view of the Braintree incinerator.

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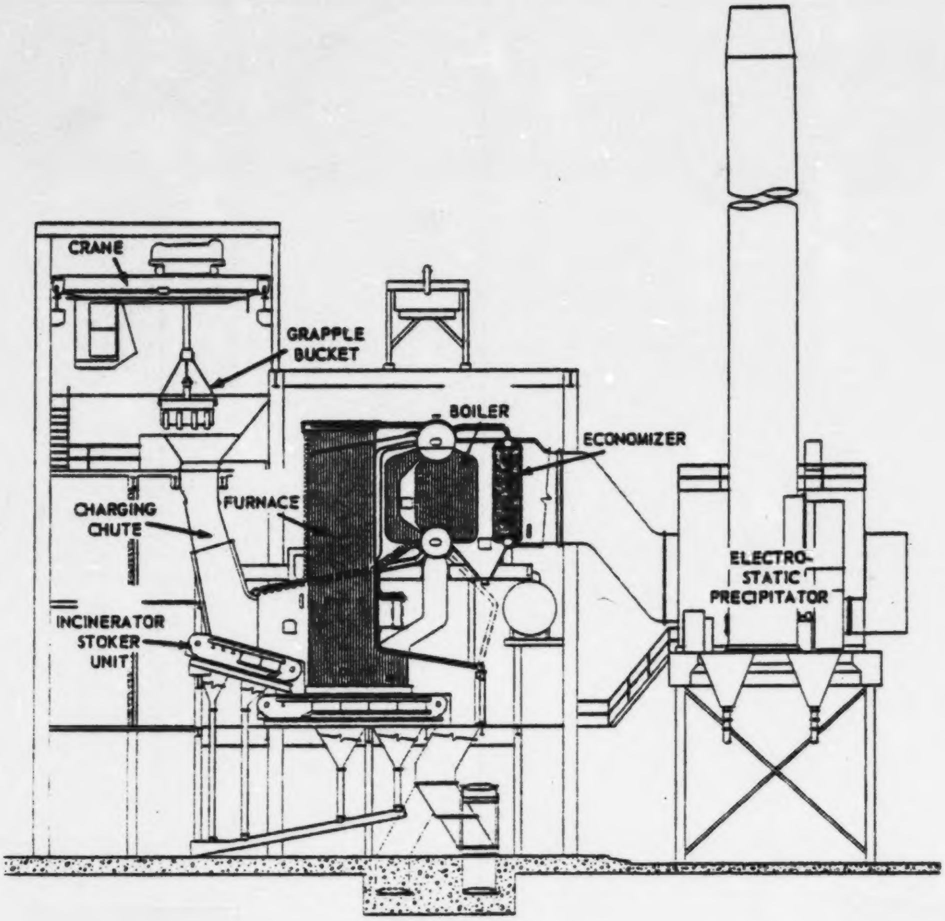
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GRAPPLE BUCKET
BOILER
ECONOMIZER
CHARGING CHUTE
FURNACE
ELECTRO-STATIC PRECIPITATOR
INCINERATOR STOKER UNIT

Figure 2. Cross-sectional view of the Braintree incinerator.

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metallic and less than 1 percent decomposable organic matter. In the past this residue has been stored on-site in the portion of the landfill not required for the MBTA development. [6,SC]

There is no processing of waste before burning, but dumping of large metal objects is not allowed. Braintree administers a source-separation program which is described in a later section, but this has little effect on the quantity or content of the waste stream entering the plant. [1,SC]

Steam Sales

The incinerator began receiving revenue from steam sales during its first year of operation (1971). Sales were apparently discontinued in 1974 and resumed again in 1975. The steam is sold to a leather factory about 200 yards from the plant on an as-demanded basis. From a 250 psig saturated condition at the plant, the steam is reduced to 100 psig superheated steam and eventually returned from the leather factory as condensate.

From an emissions standpoint, the plant has received approval to run at up to 400 tpd, but generally operates at 225-250 tpd to allow time for routine maintenance. At a firing rate of 225 tpd, the plant can produce 60,000 lb/hr of steam. About 5000 lb/hr of steam is required for internal plant uses, leaving about 55,000 lb/hr available for export (25,000 lb/hr with only one boiler operating). [3,9,SC]

The quantity of steam demanded by the leather factory varies substantially during the year since the steam is used for both heating and processing. On a peak winter day, the leather factory may require 30-35,000 lb/hr and 500,000 lb/day; during the summer, demand can fall as low as 20,000 lb/day. Capacity to export additional steam is thus available if other customers can be found, and assuming that a steady supply of waste continues to be forthcoming. A later section discusses the factors which have prevented the incinerator from expanding its steam market. [SC]

OTHER RECOVERY ACTIVITIES

Since 1976, a Braintree town committee has administered a program to recycle source-separated household waste. The committee established a recycling center near the incinerator in 1976 where residents were encouraged to bring separated glass, steel and aluminum cans, and bundled paper. Glass brought to the center has been sold for about $22 per ton, paper at from $10 to $20 per ton, and aluminum cans for $460 per ton. In 1978, the program was expanded by providing special collection vehicles which follow collection trucks on their regular daily routes to collect separated recyclables left on curbsides by households. [1,SC]

Although the recycling program currently operates at a loss of about $50,000 annually, or about $130 per ton of recycled material, the town meeting has continued to appropriate funds for its operation. It is felt that intangible benefits such as civic pride and awareness of the need to recycle waste result. [1,SC]

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It is sometimes claimed that recycling programs operating in conjunction with programs to recycle mixed municipal waste detract from the latter. In Braintree no effort is made to recycle glass and metal in mixed waste, so source-separation of these can only improve the quality of waste burned. In any case, the quantity of source-separated waste diverted in the present program is negligible compared to quantities entering the mixed waste stream.

FINANCIAL ANALYSIS

Sources of Revenue

Revenues for the Braintree incinerator are derived from three sources -- permits and tipping fees collected from commercial haulers carting waste originating outside the town, steam sales, and permits and fees collected from trucks hauling waste from commercial and industrial plants within the town. Residential waste from within Braintree is dumped at no charge, whether brought by a resident or in a collection vehicle.

Tipping Fees--

The town bases its tipping fee for outside haulers on "what the traffic will bear." The current tipping fee is $8 per ton and is thought to be competitive with tipping fees at landfills and transfer stations in the area, taking into account transportation costs. The nearest landfill in the area, about seven miles away in Randolph, Massachusetts, charges a $3.20 per cubic yard tipping fee (equivalent to $10 to $13/ton). A transfer station in nearby Weymouth, Massachusetts, charges $17 per ton. Town officials report that about 225 tpd are now being received, of which about 125 tons are from outside commercial haulers paying tipping fees. The remaining 100 tons come from within Braintree -- about 60 to 65 tpd from a five-day per week residential waste collection, and 30 to 40 tpd from commercial and industrial sources. [SC]

Steam Sales --

Steam sales to the leather factory of Weymouth Art Leather Co. are at a price which varies with the current price of oil. The incinerator must provide 100 psig superheated steam as demanded and receives $1.45 for the first 4000 lb of steam per month and $1.35 per 1000 lb thereafter, plus $0.01 per 1000 lb for each $0.075 that the price of oil rises above $8 per barrel. The leather factory receives a discount of $0.10 for each 1000 lb of steam condensate returned. [SC]

In the early years of the facility's operation steam sales were well below the $160,000 annual figure originally predicted, but since the plant reopened last year sales have increased, and are expected to bring about $200,000 in revenue for fiscal 1979. During the first four months of calendar 1979, steam revenues totaled $67,838. [SC]

The Braintree incinerator is providing steam at well below the price of a similar oil-fired boiler. For example, during April 1979 the price per barrel of oil was quoted at $20.17. At 6.3 million Btu per barrel and a boiler efficiency of 0.85, the fuel cost of steam would be $3.77 per MBtu of steam.

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The revenue obtained that month, before credit for condensate return, was about $2.96 per klb of steam, or about $2.47 per MBtu of steam, assuming 1200 Btu per lb. The steam was thus being sold for about 66 percent of its fuel value. The large discount results from the contract provision which allows the town to increase its steam price by only (100)(0.01/0.075) = 13.3 percent of the increase in the price of oil above $8. [SC]

Hauling Permits—

Haulers bringing waste from sources other than residences in Braintree are required to purchase an annual disposal permit. For non-residential sources within Braintree the permit is $10, which allows up to 1000 lb per week to be dumped at no charge, and any excess at $8 per ton. For all sources outside of Braintree the permit is $25, and all waste dumped is charged the $8 per ton tipping fee. [SC]

Imputed Town Tipping Fees—

As we have noted, municipal collection vehicles from Braintree are not charged a tipping fee for waste delivered to the incinerator, nor are tipping fees collected on the first 1000 pounds of waste per week brought in by non-residential sources within Braintree. However, it is possible to derive the foregone revenues that would have been paid by these vehicles had they paid the standard tipping fee of $8 per ton. This can be done by subtracting the tipping fees actually collected, from the dollar amount obtained when multiplying the total tonnage processed by $8. The difference is the foregone revenue. These foregone revenues appear later in our income statement for the incinerator under the heading "Imputed town tipping fees."

Statements of Income

Using annual reports from the town government, we have constructed income statements for the incinerator for the years 1971 to 1978, and estimates for the year 1979. The figures shown in subsequent pages represent our best judgment as to the incinerator's financial history. In examining these figures, the reader should nonetheless keep the following items in mind. First, as noted earlier, the collection vehicles carrying Braintree's residential waste do not pay tipping fees; we have, however, included in the revenue accounts an estimate of the fees that would have been collected had these vehicles paid the same rate as other haulers. This will allow an analysis to be made of the plant's net profit (or loss) on a comparable basis with those in other cities.

Second, in the town's accounting procedures the costs of insurance and fringe benefits are not distributed (allocated) to the department level. We have made an estimate of these expenses attributable to the incinerator using guidelines suggested by the town accountant.

Third, in January of 1973, the town changed its fiscal year to run from July to June rather than from January to December. Thus fiscal year 1974 extends for 18 months from July 1973 to June 1974; for this reason no fiscal year 1973 is shown on the books.

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Fourth, in May of 1976 the incinerator was ordered closed by the state Department of Environmental Quality, along with other incinerators throughout the state. The shutdown came about as a result of a new state air quality standard for particulates adopted in 1976. Repairs, modifications, and testing took over two years, with the plant resuming normal operations in August 1978. No waste was processed, therefore, during fiscal year 1977, and modest amounts in fiscal year 1978. In addition, a large expense was incurred for rubbish removal and for the modifications themselves. While the latter might well be considered a cost that should be capitalized, they are nonetheless expensed on the town's books and thus produce a bulge in annual expenditures.

Conventional Analysis—

Key financial and operating data for the incinerator are shown in Table 12. As can be seen, revenues came predominantly from tipping fees until 1975, when steam sales began in earnest. Revenues dropped to zero in 1977 while the plant was closed and then rebounded in 1978 during testing and startup after the closure. The tipping fees attributable to town sources (but not paid directly) represent the largest revenue source throughout the period under consideration.

The capital cost of the original plant and equipment was financed with a bond repayment structure such that principal is repaid in constant annual amounts and thus interest and total debt service decline over time. At the same time, however, operating costs have increased in all areas -- labor, maintenance, and utilities. Increases in the latter have been particularly rapid and reflect in part the need to burn natural gas when the plant is not in operation. Initially this meant gas firing on third shift and weekends and resulted in rapidly growing gas bills. With the change to longer operating hours the use of gas has declined appreciably.

Residue from the plant was originally intended to be disposed on site in the remaining area of the former landfill. However, recent changes in state laws have resulted in the classification of the residue as organic waste. This has meant that accumulated residue on site must be removed and that in future residue must either be provided with daily cover or else hauled to a sanitary landfill. [9,SC]

With the closing of the plant in May of 1976, the town began to incur heavy expenses for removal of rubbish to other disposal sites. The effect on expenditures is quite dramatic in 1977, and to a lesser extent in 1978. Note also the considerable bulge in the "Other supplies and services" category between 1976 and 1978. Included in these three years is about $500,000 in modifications for air pollution control purposes, financed in part by a $300,000 federal revenue sharing allotment. [1,SC]

When revenues and expenses are compared, the pattern observed is one of fluctuating but rather large losses. Throughout the period 1971 to 1979, revenues have not been sufficient to cover variable costs, much less debt service, even when imputed town tipping fees are included. The situation

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TABLE 12. OPERATING DATA, BRAINTREE, MASSACHUSETTS INCINERATOR PLANT
(All dollar amounts in thousands of dollars, except per ton amounts)

	1971	1972	1974[1]	1975	1976	1977	1978	1979[2]
Operating revenues								
Tipping fees	43	34	37	63	34	0	14	118
Permits	4	2	3	3	7	0	4	5
Steam sales	6	5	0	87	61	0	66	157
Imputed town tipping fees	na	153	144	145	139	0	192	269
Total operating revenue	na	195	184	299	241	0	277	550
Operating expenditures								
Salaries & wages	99	164	286	243	215	89	301	346
Fringe benefits[3]	33	54	95	80	71	29	99	114
Maintenance	18	46	129	105	64	50	75	98
Utilities	41	81	105	94	140	19	104	170
Insurance[3]	7	16	34	18	25	26	29	40
Rubbish removal	0	0	0	0	5	198	97	21
Disposal	0	1	28	10	16	33	7	31
Equipment	0	0	11	4	3	3	2	26
Other supplies and services	101	24	163	45	126	183	286	29
Interest on debt	109	103	141	87	81	75	69	62
Debt retirement	140	140	210	140	140	140	140	140
Total operating expenditures	547	630	1203	827	884	846	1208	1077
Operating profit (loss)	na	(435)	(1018)	(528)	(644)	(846)	(932)	(527)
Net Cost of Disposal	541	625	1203	740	823	846	1142	920
Refuse processed (10^3 tons)	na	23	23	26	22	0	26	48
Operating revenue per ton	na	8.33	8.14	11.47	11.14	nm	10.74	11.35
Operating expenditure per ton	na	26.90	53.26	31.76	40.96	nm	46.91	22.24
Operating profit (loss) per ton	na	(18.58)	(45.11)	(20.28)	(29.81)	nm	(36.17)	(10.89)
Net disposal cost per ton	na	26.67	53.26	28.41	38.12	nm	44.33	19.00

1. Fiscal years 1971 and 1972 ran from January to December; fiscal year 1974 includes 18 months from January 1973 to June 1974; fiscal years 1975 to 1979 run from July to June.

2. Estimated for 1979; see footnote on Sources below.

3. Fringe benefits have been calculated as 33 percent of salaries and wages; insurance has been calculated as the total of boiler insurance plus 20 percent of the fire insurance premium for the town.

na = Not available.

nm = Not meaningful.

Sources: Town of Braintree annual reports for the years 1971 through 1978. For the year 1979, revenues and tonnages are actual amounts while expenditures represent amounts appropriated for use during the year.

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looks somewhat worse than it actually is, for as we noted earlier, the modifications made in response to the state's closure have been expensed rather than capitalized in the town's accounts. Note that the picture is projected to brighten considerably in 1979 with the increased tipping fees and steam revenues and the completion of plant modifications.

Of particular interest is the bottom line in Table 12, which shows the per ton net cost of disposal. The net cost of disposal can be defined as total operating expenditures, less revenues from the sale of scrap and steam. As can be seen, the per ton cost of disposal has varied between $27 and $53 through 1978. This about two to three times the price charged during that period by the landfill and the transfer station which are located to the south and east of Braintree, respectively. Note also, however, the large decline in per ton cost projected to occur in 1979 as a result of the increased revenue contribution from steam sales and much higher throughput. At $19 per ton, the incinerator is providing disposal service at a cost which is comparable to that now charged by the transfer station in nearby Weymouth ($17/ton). It is also comparable to a price quote ($20/ton) recently received from a commercial hauler for using the incinerator location as a transfer station and hauling all waste to a landfill. [8]

The incinerator's probable financial picture for the near future is difficult to forecast. In fiscal year 1980, the facility goes to seven days a week operation and thus in theory could expand throughput considerably. In fiscal year 1979, availability of waste was not a limiting factor and the plant ran at about 78 percent of capacity for a five-day-per-week operation (48,438 tons/260 days/240 tpd x 100). If the same utilization rate can be maintained over a 340-day-per-year schedule, the per ton cost of disposal could drop well below the $19 level reached in 1979.

On the other hand, the schedule change is a one-time fix whose beneficial effects on cost will continue in subsequent years but in a less dramatic way. The main concern must be whether revenue growth can be sustained at a level which will offset inevitable increases in labor, utilities, and other expenses. Some revenue growth will come from steam sales, although perhaps not as large as one might expect. The quantity of steam that can be sold is demand-limited, as we have noted earlier. And the price of steam will not grow nearly as fast as the price of oil because the escalation clause limits the town to 13 percent of any increase. Over time, then, it is possible that the town will have to increase tipping fees and the question is whether it will be able to do so without losing the cost comparability that was finally reached with land disposal in 1979. Or alternatively, the town may need to consider renegotiating its present steam contract.

Replacement Cost Analysis—

A somewhat different view of the situation is provided when the income statement is recast with the facility shown at its replacement cost rather than in terms of its historical cost. An income statement using replacement cost would be indicative of the incinerator's financial position if the

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facility were constructed in the current year. Hence, the replacement cost income statement is the one which other cities should look at if they are in the process of considering a resource recovery project. In general, if construction costs have escalated at a faster rate than other revenue and expenses categories since the original construction period, then the financial picture will appear worse compared to the historical cost basis. If construction costs have escalated at a lower rate, then the financial picture will appear better than the historical cost income statement.

Our best estimate is that the replacement cost for the facility would be about $6.9 million. This figure was obtained by escalating the basic facility cost of $2.8 million* in 1968 to the current year 1979 using the Handy-Whitman index of utility construction costs. Assuming that this amount would again be amortized over 20 years but that an interest rate of 7 percent would now be required, the annual cost would be $655,000. When this figure is used in the estimated income statement for 1979, a net loss of $980,000, or $20.23 per ton, is obtained. The corresponding net cost of disposal also increases to $1.37 million, or $28.33 per ton. These figures are larger than those shown in Table 12 because construction costs have risen more rapidly than the general price level, and because interest rates are higher. In effect, this means that if Braintree were going to invest in resource recovery, it is better to have done so when it did rather than to have waited until 1979.

COMPARISON OF PLANNED VS. ACTUAL RESULTS

Braintree's experience with the incineration project has differed from its expectations in several respects. These differences are summarized briefly below. We should stress that in making these comparisons our intention is simply to identify past problem areas so as to improve future efforts at resource recovery.

Cost of Operations

The Braintree incinerator has experienced operation and maintenance costs (O&M) which are considerably higher than had been anticipated. In the 1966-67 period when the original design studies were being done, the expectation was that O&M would run $169,000 per year as noted earlier. In the first full year of operation (1972) actual expenses for O&M were $390,000 and in subsequent years O&M has grown steadily, reaching an estimated $874,000 in 1979.

Some of the increase can be attributed to accounting treatment of certain expenses such as final payments for plant construction and payments for plant modifications. As we have noted, one could argue that these expenses could be capitalized rather than showing them as a current expense. Some of the increase can also be attributed to changes in the general price level. For

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* This includes the construction cost of $2.6 million plus $0.2 million for the initial engineering studies.

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example, when the 1972 O&M figure is converted to constant 1967 dollars,* it becomes $294,000. When all of these adjustments are made, the resulting expense for O&M ranges between $252,000 and $422,000 per year in 1967 dollars. The remaining difference over $169,000 represents the extent to which costs were underestimated. The increased expenditures, as we have noted previously, have been primarily for utilities (especially natural gas, and more recently, electricity), residue disposal, rubbish removal, and maintenance.

Steam Sales

Original expectations were that revenues from the sale of steam would amount to $160,000 per year. In fact, however, they did not reach this level until 1979, by which time the price of oil had increased severalfold over its 1967 level. If the $160,000 figure was based on residual oil at $2.75 per barrel,** then the equivalent steam revenues with the present $20 per barrel oil would be $1.16 million, or seven times larger than actually received in 1979.

The low steam revenues, as we have noted earlier, can be traced to two sources -- the price escalation clause in the steam sales agreement between the town and the leather factory, and the factory's limited and fluctuating demand for steam.

A variety of factors has prevented the Braintree incinerator from expanding its steam market. Given the town's size and density a district heating system, which might be an attractive use for low-temperature steam in a larger city, is impractical. A recent proposal to sell steam to the municipally-owned electric utility was rejected because it would require tripling the size of the plant and incurring an additional $35 million debt. A more modest proposal to sell steam to a local Armstrong Cork Company plant was estimated to cost $750,000 for a steam line that would generate a prospective $300,000 in annual revenues, but this would have required continuous operation of both boilers and thus hampered maintenance. Braintree is currently investigating a proposal by Pyro-Magnetics Company to build an additional plant adjoining the incinerator to process the incinerator's residue with a high-temperature process which would extract metal as slag and produce a silica-based product for insulation and road material. The plant would provide revenue from both steam sales and sale of process materials. [4,8,9]

Operating Problems

The incinerator has had very successful operational performance, characterized by high levels of equipment availability and waste throughput, since August 1978 when the plant resumed normal operations after a closure by the state. In earlier years, however, some operating problems did develop which in several instances proved to be quite costly. Foremost among these was the corrosion of the electrostatic precipitators and deterioration of the economizers* which resulted from repeated startups and shutdowns of the plant. Although the incinerator was designed to be fired with natural gas when not burning waste, it was often closed down completely at nights and on weekends during its early years of operation. During shutdown the temperature would fall below the acid dew point, allowing sulfuric acid to form and produce corrosion; meanwhile the repetition of startup and shutdown led to deterioration of the economizer tubes. These problems contributed to the plant's difficulty in meeting state air quality standards which were later adopted and eventually necessitated costly repairs. As one of the first users of what was then a relatively new technology (refuse-firing and electrostatic precipitation), the town has had to develop some of its "standard operating procedures" by trial and error. [9,SC]

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* Using the implicit price deflator for Gross National Product.

** The average refinery price for No. 6 residual oil in the Boston area was $2.39 per barrel in 1967. The delivered price would thus be in the $2.50 to $3.00/bbl range.

The issue of air quality standards also deserves further discussion. At the time the plant was originally designed (1966-67), the decision was made to incorporate electrostatic precipitators, described then as the best available control technology. This design proved to be adequate for complying with the federal air quality standard for particulates, in effect when the plant passed acceptance tests in mid-1971 (0.1 grains of particulate per dry standard cubic foot of air). At that time the state had no separate standard. Later in the year, however, the federal EPA published a new standard of 0.08 grains per standard cubic foot, followed in 1976 by a state standard of 0.05 grains per standard cubic foot. Since this new state standard apparently could not have been met even if the efficiency of the precipitators had not been degraded by corrosion, the incinerator was ordered closed by the state in May of 1976. [3,9]

CONCLUSIONS

In this section we attempt to answer three questions: First, is the Braintree resource recovery operation economical? Second, if it is not, can this be attributed to the impediments catalogued in the Appendix? And third, what changes would be necessary to overcome these impediments?

Is the Facility Economical

In the accounting sense of producing revenues in excess of costs, the Braintree incinerator is not at present economical. The facility's revenues have not been sufficient to cover fully the annual costs of operation and maintenance, nor thus to cover the required annual payment of interest and principal on the original debt. The remaining costs are paid for by Braintree property owners through general taxation.

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* Economizers are heat exchangers which are used to preheat the boiler feedwater using waste heat recovered from the exhaust gases.

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In the broader sense of providing the least costly disposal alternative, the incinerator comes closer to being economical. While the per ton cost of disposal varied between $27 and $53 in its first years of operation, in 1979 the per ton cost fell to $19. The latter is comparable to the cost of transfer station service in the area (though some landfills are still in the $10 to $13 range). Because the incinerator must compete with landfilling for non-Braintree waste in order to generate the high level of throughput that makes the $19 per ton cost possible, the tipping fee has been set at the $8 per ton level. This means that Braintree sources must pick up the difference in cost, thus raising the net disposal cost for Braintree sources to perhaps $22 or $23 per ton.

Financial prospects in the 1980's are difficult to predict. Expenses, particularly for utilities and residue disposal, will continue to grow. Revenues, meanwhile, should get a continuing boost from the shift to seven days per week operation assuming that the anticipated additional waste volumes will be forthcoming. Nonetheless, it appears likely that there will be continuing pressure to raise the tipping fee, to renegotiate the steam contract, and to develop additional steam markets in order to maintain the cost comparability with transfer station service that was finally attained in 1979. However, speculation on whether these events will actually occur, and on what their financial implications are likely to be, is beyond the scope of this study.

What Have Been the Impediments to Economical Operation?

Table 13 lists the various impediments to economical resource recovery catalogued in the Appendix, along with qualitative ratings of how each impediment has affected the experience at Braintree. The following discussion summarizes the results presented in the table.

In our judgment, much of Braintree's financial difficulty with the incinerator stems from its inability to command a higher tipping fee for waste brought in from outside the town. In order to generate a high level of throughput, the town has found it necessary to price its service at $8 per ton even though its average disposal cost in the most recent year was about $19 per ton. The reason for the discrepancy between price and cost, in turn, is that land disposal alternatives are available to surrounding communities at prices well below $19 per ton. While we have no specific evidence that the low cost of these alternatives is related to the pricing of land disposal below full social cost, we suspect that this is the case and that strict enforcement of RCRA* provisions relating to landfill would eliminate much of the competitive advantage which the landfills now enjoy. If this is the case, then failure to price land disposal in the area at full social cost has been the most significant impediment to economical operation of the incinerator in the past.

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* The Resource Conservation and Recovery Act of 1976.

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TABLE 13. IMPEDIMENTS TO ECONOMICAL OPERATIONS (BRAINTREE, MA.)

Impediment	No effect evident	Some effect probable	Large effect probable
Restrict quantity or composition of waste			
Pricing of landfills below full social cost			x
Independent source-separation programs	x		
Returnables policy for bottles and cans	x		
Fragmentation of local government		x	
Restrictions on interstate movement of waste	x		
Seasonal or business cycle fluctuations	x		
Increase initial cost or restrict design			
Inadequacies of available technology	x		
High unit cost for equipment and parts	x		
Limited design experience	x		
Limitations on municipal financing	x		
Low first cost approach to public contracting	x		
Affect cost or efficiency of operations			
Limited operating experience		x	
Limited availability of spare parts	x		
Shortage of required labor skills including supervision	x		
State and federal regulation of air quality		x	
Restrictions on disposal of ash and residue		x	
Limit markets for available products			
Siting restrictions	x		
Franchise restrictions on steam and electric sales	x		
Tax subsidies for virgin materials		x	
Price controls on oil and gas		x	
Lack of futures markets for scrap	x		
Unpriced mining and processing costs	x		
Differential freight rates	x		
Lack of product standards for reclaimed materials	x		
Rate regulation of electric utilities	x		
Restrictions on use of ash, residue and shredded materials	x		
Product labeling restrictions	x		
Government procurement policies	x		

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Also not to be discounted is the effect which various state government policies have had on Braintree's operations. The town had begun its plans for resource recovery in advance of a well-defined policy framework at the state level. There were no agencies charged with the responsibilities for state or regional solid waste management planning; there were, as we have seen, no state standards regarding air pollution; and there continue to be state laws which prohibit the use of residue for roadbuilding and instead require that it be covered when landfilled.

The town was thus in the position of being the first to use a new technology and of bearing the accompanying risks. Although the original plant design met the then-current federal standards for air quality, it could not comply with subsequent stricter federal standards and even more strict state standards later adopted. Braintree was forward-looking enough to develop the nucleus of a regional waste disposal facility, but practical efforts to effect this program have been frustrated, both by lack of cooperation from other municipalities and at times by actions of the state. For example, when Braintree sought to reach an agreement with the nearby town of Weymouth to receive its waste, a state pronouncement that Braintree would have to provide backup landfill arrangements reportedly killed the plan. And although residue has been used in Europe for roadbuilding, and approved for this purpose in other U.S. states, the town is faced with the prospect of paying $18 per ton or more for residue disposal. [9,SC]

Other impediments which probably have had some effect include: limited operating experience with the new technology which led to premature deterioration of the precipitators and economizers; and tax subsidies and price controls for oil which reduce oil prices and thus the price that can be obtained for waste-generated steam.

What Changes Would Make the Facility Economical?

To illustrate the sensitivity of the incinerator's income statement to various parameters, we carry out below some sample calculations. It should be stressed that the calculations represent order of magnitude estimates and do not take into account a variety of factors that would be considered in a more detailed study of the facility. The sensitivity analysis is conducted with respect to the financial results projected for 1979.

Increases in Throughput--

The first question of interest is the level of throughput that would be required for breakeven operation. It turns out that no breakeven level exists for the prices and costs prevailing during fiscal year 1979. This conclusion can be seen as follows. First, the maximum throughput which the plant could reasonably hope to obtain is about 70,000 tons per year. This would be based on operations at 85 percent of the 240 tpd capacity for 340 days of the year. Revenues from tipping fees, including imputed tipping fees for the town, at 70,000 tons would be ($8 x 70,000 tons) = $560,000. Expenses at this level of throughput would probably run $1 million, as in 1979, plus the additional costs for weekend operation. This would mean that a deficit in excess of $440,000 would have to be offset by steam revenues. Since steam revenues in

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1979 were about $157,000 and the steam customer was getting about all that he needed, breakeven operation could not be brought about through increases in throughput alone.

Increase in Landfill/Transfer Station Prices—

If the incinerator could increase its tipping fee by $10.89 per ton, its projected 1979 loss would be erased. An increase of this size could be sustained without losing customers to the competing landfills if the latter had to increase their prices by the same dollar amount. In the case of the landfill in Randolph, this would represent an increase of about (100)(10.89/13.00) = 79 percent. While strict enforcement of RCRA might produce large increases in landfill prices, it is unlikely that the increases would be as large as this.

Increase in Oil Prices—

An increase in steam revenues of $527,463 would also erase the deficit projected for 1979. To achieve this increase without increasing the quantity of steam sold would require an increase in the price of steam and thus in the price of oil. If we assume that the 1979 steam revenues are based on steam sales of 60-80 million pounds per year, then the required increase in the price of oil is about $45 to $65, or 200-300 percent over its current level. The required increase is so large because, as we have noted, the steam price can be increased by only 13 percent of the increase in the price of oil. While continued large increases in the price of oil are likely, it seems unreasonable to expect that they would be of this magnitude, at least in the near future.

Combinations of Changes—

We have not explicitly considered above the possibility that several factors could be changed simultaneously. We have looked only at individual factors and found that a change in any one factor will probably be insufficient to bring about breakeven operation. Indeed, the analyses above suggest that a combination of changes -- higher throughput, higher oil prices, and probably higher landfill tipping fees may be necessary. Fortunately for Braintree, this is the scenario that will most likely take place.

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3. Heaney, Frank L., "Air Pollution Control at Braintree Incinerator," APCA Journal, 22:617-620, August 1972.

4. Metropolitan Area Planning Council, Community Exchange Series: Resource Recovery, April 1979.

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ACKNOWLEDGMENTS

We are grateful to Mr. Robert K. Sherman, Executive Secretary (town manager) to the Braintree Board of Selectmen, and Mr. Ed Courchene, Plant Superintendent of the Braintree incinerator, who provided information and material in addition to the references cited above. Reference to information contributed by Mssrs. Sherman and Courchene is denoted by the letters "SC" appearing in the text.

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SECTION 5

NORTH LITTLE ROCK, ARKANSAS

SUMMARY

The city of North Little Rock, Arkansas owns a modular incinerator plant with a capacity of 100 tons per day (tpd). Until recently, the plant was operated by the city, burning all of the city's refuse and generating steam for sale to a nearby factory. During the first 21 months of operation, the plant had reached a level of throughput averaging above 80 percent of rated capacity and had experienced no long-term shutdowns for repairs. However, problems with labor and management turnover led to a rapid deterioration of the plant in the period following our visit, so that when a change in the city administration occurred two months later, the new administration decided to close the facility (September 1979). The city is now negotiating with the incinerator manufacturer to have the latter operate the plant for the city, with reopening scheduled for early 1980.

BACKGROUND

Area Characteristics

North Little Rock is located across the Arkansas River from the larger state capital city, Little Rock. North Little Rock's 1975 population of 61,768 is somewhat less than half that of its larger neighbor, and the city has seen its population decline slightly in the 1970's following moderate growth in the previous decade. The city's employment base mirrors that of Little Rock with 17 percent employed in manufacturing, 23 percent in retail and wholesale trade, 17 percent in government, and the remainder primarily in the service industries.

Historical Methods for Solid Waste Disposal

Prior to construction of the incinerator, North Little Rock disposed of its waste in a private landfill. For city trucks, which collect all household and most commercial waste in the city, the round trip distance to the landfill was about twenty miles on average. The landfill was not providing daily cover at the time and it was estimated that providing cover would have increased tipping fees by about 75 percent. This prospect, together with the length of the haul to the landfill, led the city to begin investigating alternative disposal possibilities around 1970. [5,W]

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At one point the city considered the possibility of purchasing an unused quarry, located somewhat closer to the city. This option was rejected, however, when it was found that to use the quarry site as a landfill would have required installing a protective seal against leachate, at considerable expense. [W]

Initial Planning for the Facility

With available opportunities for landfill disposal appearing unattractive, the city began to look into resource recovery possibilities. Sometime later, in 1971, the city sold $260,000 in sanitation improvement revenue bonds, of which $146,800 was used to purchase two Consumat Model H760 incinerators and $37,550 was used to purchase a prospective site for construction of an incinerator plant. One version of the initial plan called for siting three incinerators in the north, east, and central parts of the city to further reduce hauling costs, but objections from potentially affected residents and a neighboring town in which one of the incinerators was to be located prevented implementation of the plan. The incinerators which had been purchased were thus never installed; the land purchased was not used for this purpose either, although the city did retain ownership. [5,W]

In 1976 the city decided to try again. This time the project was aided by a steam sales agreement between the city and the Koppers Corporation, headquartered in Pittsburgh, but with a factory in North Little Rock. The local factory produces forest products, including railroad ties which the factory impregnates with creosote using steam. Under the agreement signed in 1976, the Koppers Corporation agreed to lease to the city a 2.25 acre plot of land adjacent to its factory. The lease is for a term of 20 years at $1.00 per year and includes a purchase option for the city. The city in turn agreed to build an incinerator on the site to burn municipal refuse and provide the factory with steam. [2,5,6]

A bond prospectus, issued in conjunction with a June 1976 offering of revenue bonds to finance the incinerator, contained an estimate of anticipated revenues and expenses. The estimates for fiscal years 1977-1980 (fiscal year ends April 1) are shown in Table 14 below. Note that the figures include revenues and expenses for both municipal collection and disposal since residents pay for both together. [5]

FINANCING AND CONSTRUCTION OF THE FACILITY

In 1976 the city sold an additional $1,300,000 in sanitation improvement revenue bonds to finance construction of the incinerator facility. These funds, together with $73,000* in other city funds and a credit of $146,800 which Consumat provided the city in exchange for return of the earlier boilers, financed a total capital cost of $1,520,000. A breakdown of the capital cost is provided in Table 15. Following construction, the plant began operations in September 1977. [5]

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* These were funds still available from the 1971 bond issue.

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TABLE 14. ANTICIPATED REVENUES AND EXPENSES

	1977	1978	1979	1980
Collection fees	$512,000	$635,000	$635,000	$635,000
Steam sales	82,125	136,600	182,300	206,900
Tipping fees - private	31,500	52,000	52,000	52,000
Total revenue	$628,625	$823,600	$869,300	$893,900
Collection expenses	$390,000	$425,000	$445,000	$460,000
Plant operation	105,000	155,000	180,000	190,000
Total expense	$495,000	$580,000	$625,000	$650,000
Net income	$133,625	$243,600	$244,000	$243,900

Source: [5]

TABLE 15. CAPITAL COSTS FOR THE NORTH LITTLE ROCK INCINERATOR ($1,000's)

Site preparation	$ 101
Design	38
Construction	311
Real equipment	969
Other equipment	63
Other costs	38
Total	$1,520

Source: [8]

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OPERATION OF THE FACILITY

Until the recent closure of the facility, the operating hours of the plant were 24 hours per day, five days per week, with shutdown over the weekends. The operating schedule corresponds to the hours during which the city is obligated to provide steam to the adjacent factory under terms of the steam sales agreement. The plant was staffed by 11 employees including a plant manager and a secretary. It is expected that the same operating schedule and manpower level will be used when the plant is reopened. [6,MG]

Description of the Facility

The plant is built around four-25 tpd modular incinerators manufactured by Consumat Systems, Inc., of Richmond, Virginia. The units are arranged in pairs at opposite ends of the plant, as shown in Figure 3, so that two completely independent processing lines are available. The units are equipped with semi-continuous ram feeders for the refuse, semi-continuous ash discharge systems, automatic combustion controls and waste heat recovery boilers. Each pair of units is designed to raise approximately 10,000 lb/hr of steam when firing 4500 Btu/lb as-received solid waste. On average, the steam is produced at 130 psia (115 psig) and 350^{O}F, with variations around this condition as steam demand from the factory changes. [7,8]

Waste on the tipping floor is handled with a rubber-tired front-end loader which services both ends of the plant. At each end, the waste is pushed into the 2.5 cubic yard reversible shuttle ram feeder which advances the waste into the primary chamber of the incinerator. A load level sign indicates to the loader operator the amount of waste to be fed in on each load in order to help control the combustion temperature. Unprocessible material such as large metal objects, white goods, and hazardous materials are removed from the tipping floor and placed in the residue containers for disposal. [7,8]

Air pollution control is accomplished by careful combustion control without the use of particulate removal equipment or auxiliary fuel during normal plant operation. The CO-rich smoke from the primary combustion chamber is burned to completion in a secondary chamber which operates at about 1800^{O}F compared to about 1200^{O} in the primary chamber. The hot gases from the secondary chamber are passed through a heat exchanger where the temperature of the gas is reduced from 1800^{O}F to 450^{O}F in order to produce steam. During startup periods natural gas is used to bring the secondary chambers up to firing temperatures. [7,8]

Ash from the primary chambers is periodically discharged by a ram through a water-cooled chute to a water-quencher. After 15 minutes the ash is conveyed up to an inclined trough for dewatering and discharged into removable bins. The total processing time from raw refuse to quenched residue is estimated to be about nine hours. The residue is currently taken by a private land developer for fill material at no expense to the city. [MG]

The plant was designed to meet a state-imposed particulate standard of 0.2 grams per dry standard cubic foot of air, corrected to 12 percent CO_2.

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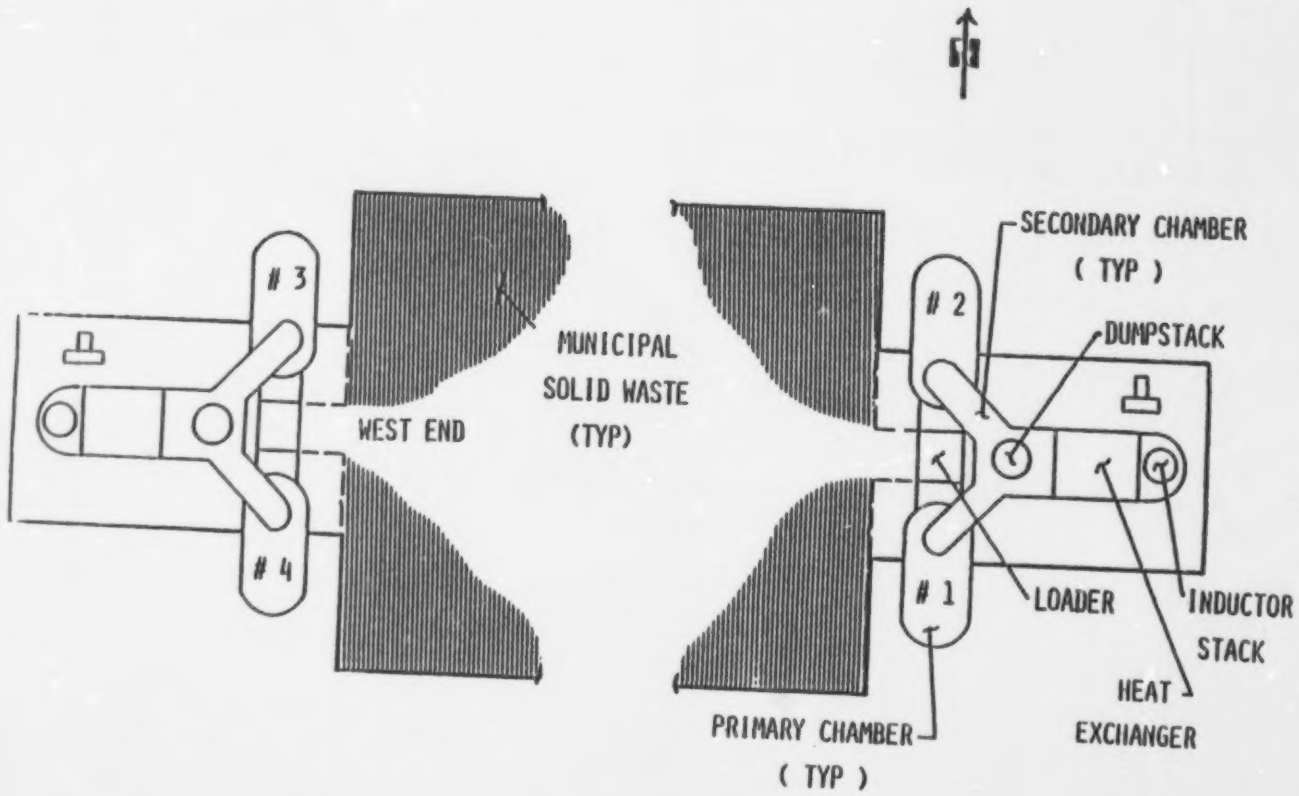
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Figure 3. Schematic of the North Little Rock resource recovery facility.

Source: [7]

Recent field tests at the facility at three different times (March, May, and October of 1978) indicated that emissions ranged from .07 to .28 gm/SCF and averaged 0.14, 0.19, and 0.13 on each occasion. These performances met the state standard but are higher than the current federal standard of 0.08 gm/SCF for municipal incinerators with greater than 50-tpd capacities. However, this standard apparently does not apply to the North Little Rock facility because each pair of incinerator units is rated at 50 tpd. [8]

Steam Sales

The Koppers factory next door to the facility processes about 100,000 carloads of railroad ties annually and uses steam from the incinerator to impregnate the ties with creosote, a wood preservative. The contract between Koppers and the city requires the city to make available 15,000 lb/hr of dry, saturated steam at 110 to 150 psig for 24 hours a day, 260 days per year. Koppers also has the option under the contract to request steam service over the weekends if it makes the necessary waste available to the city. [6]

Until the recent closure of the incinerator, steam service was being provided on a five-day-per-week basis and steam demand from the factory was averaging 10-11,000 lb/hr, or somewhat less than the city had expected. Under the terms of the contract, the factory is required to pay only for steam it actually uses. Capacity to supply additional steam is thus available, if an additional customer can be found, since the plant is capable of producing up to 20,000 lb/hr of steam depending on the heating value of the refuse. The plant was designed to burn 4500 Btu/lb refuse, but recent tests have estimated that the refuse as received is running about 3800 Btu/lb. [3,6,7,8]

Materials Recovery

No materials recovery takes place on a commercial scale at the North Little Rock facility and none is planned. Large ferrous metal items are sometimes hand-separated from incoming waste by plant employees and sold to scrap metal merchants in order to provide petty cash items. During the planning of the facility some consideration was given to recovery of glass and metal, but markets for these items were judged insufficient. [MG]

FINANCIAL ANALYSIS*

Sources of Revenue

Revenues for the North Little Rock incinerator are derived from two sources -- tipping fees collected from commercial haulers and steam sales to the adjacent factory. Residential waste (and some commercial waste) collected by municipal trucks in the city is dumped at the incinerator at no charge.

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* The financial data and arrangements discussed in subsequent sections relate to conditions prior to closure of the plant in September 1979.

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Tipping Fees—

The plant accepts all waste collected by the city's municipal collection service, which includes all residential waste and some commercial waste. In 1976 there were 20,512 residential customers and 452 commercial customers. Private collectors haul the remaining commercial waste and industrial waste, including some waste from outside the city. The private collectors pay a tipping fee of $1.00 per cubic yard for waste brought to the incinerator, although private trucks are turned away at times when the plant is operating at capacity. These trucks must then presumably make the 20-mile round trip out to the older landfill, where the tipping fee is also reportedly $1.00 per cubic yard. [5,MG,L]

In 1978, municipal vehicles brought 14,893 tons (49,000 cubic yards)* to the facility; private haulers brought slightly more than 5000 cubic yards. [1]

Steam Sales—

Steam which is sold to the factory is based on the prevailing price of natural gas or No. 2 oil, whichever is lower. The steam price per 1000 pounds is taken to be 1.5 times the fuel price in dollars per MBtu, less a discount whose percentage increases as the fuel price increases. The net result is a price per 1000 pounds which is 1.5 times the fuel price for fuel prices of $0.80 per MBtu or less, and which falls to 1.05 times the fuel price for fuel prices of $3.00 per MBtu or more. [6]

In 1978 the incinerator generated a total of 106,080,000 pounds of steam, of which the factory used 67,894,000 pounds, or 64 percent. The steam sold provided revenues of $161,250, indicating that the steam sold for an average price of $2.38 per 1000 pounds. [1]

Imputed City Tipping Fees—

As we have noted, municipal collection vehicles from the city are not charged a tipping fee for waste delivered to the incinerator. However, it is possible to derive the foregone revenues that would have been paid by these vehicles had they paid the standard tipping fee of $1.00 per cubic yard. This can be done by subtracting the tipping fees actually collected, from the dollar amount obtained when multiplying the total tonnage processed by $3.33. The figure of $3.33 is obtained by converting the per cubic yard fee of $1.00 to a per ton fee using the city's estimate of 0.30 tons per cubic yard. This calculation yields the foregone revenue, which we show later in our income statement for the incinerator under the heading "Imputed city tipping fees."

Statements of Income

Using unpublished cost accounting records provided by the city, we have constructed income statements for the incinerator for the year 1978, and for

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* The estimate of 0.30 tons per cubic yard for the city's waste is taken from the 1978 annual report for the plant. [1]

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the partial years 1977 and 1979. The figures shown in subsequent pages represent our best judgment as to the incinerator's financial history. In examining these figures, the reader should nonetheless keep the following items in mind. First, as noted earlier, the collection vehicles carrying the city's residential waste do not pay tipping fees; we have, however, included in the revenue accounts an estimate of the fees that would have been collected had these vehicles paid the same rate as other haulers. This will allow an analysis to be made of the plant's net profit (or loss) on a comparable basis with those in other cities.

Second, the plant began operations in September 1977 and was closed on September 25, 1979. Thus, the only year for which complete operating data are available is 1978. The data for 1977 represent actual figures for the period of operations. The data for 1979 cover only the period through May 1979 and include both actual and estimated data.

Conventional Income Analysis—

The key financial and operating data for the incinerator are shown in Table 16. As can be seen, revenues have come predominantly from sales of steam to the factory. In the full year 1978, steam revenues accounted for about 75 percent of total revenues even when tipping fees imputed to the city are included. City vehicles in turn brought in about 90 percent of the refuse processed and have been credited with providing an equivalent amount in tipping fees (though such fees were not paid directly). Tipping fees from private haulers are less than 3 percent of total revenues at present. [1]

The city was able to reduce substantially the use of natural gas at the incinerator during the period of 1979 for which we have data. This is in contrast to higher levels of usage in 1978, and the reduction is readily apparent on the income statement when expenses for utilities in the two years are compared. [3]

One item which we have not included in the income statement but which the city correctly views as a benefit from the incinerator is the savings from not having to haul waste to the more distant landfill. In 1978 the city estimated the savings to be $8,000 in fuel and vehicle maintenance costs. No direct savings in labor costs are realized because collectors are paid on a task basis rather than at an hourly rate. The fuel and maintenance savings nonetheless work out to be about $0.54 per ton ($0.16 per cubic yard). [1]

When revenues and expenses are compared, we see that in 1978 the plant was easily covering all variable expenses and paying about one-third of the cost of debt service. In 1979 our estimate is that through May the plant was running ahead of the previous year on the revenue side, but was also experiencing considerably higher costs, particularly for equipment maintenance. Overall, we project a slightly higher loss per ton during the first five months, compared to the previous full year ($8/ton vs. $6/ton). Omission of the savings in transportation costs to the landfill does not appreciably affect these results.

Of particular interest is the bottom line in Table 16, which shows the net cost of disposal per cubic yard. The net cost of disposal can be defined

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TABLE 16. OPERATING DATA: NORTH LITTLE ROCK, ARKANSAS MODULAR INCINERATOR
(All dollar amounts in thousands of dollars, except per ton amounts)

	1977[1]	1978	1979[2]
Operating revenues			
Tipping fees-private hauler	na	5	
Imputed city tipping fees[3]	na	50	
Steam sales	na	161	75
Total operating revenue	na	216	102
Operating expenditures			
Salaries, wages and fringes	34	83	55
Utilities and communications	13	56	15
Other supplies and services	7	29	45
Debt service	0	148	54
Total operating expenditures	54	316	169
Operating profit (loss)	na	(100)	(67)
Net disposal cost[4]	na	155	94
Refuse processed (10^3 tons)	na	16.4	8.2
Steam produced (10^6 lbs)	na	106.1	na
Steam sold (10^6 lbs)	na	67.9	27.0
Operating revenue per ton	na	13.17	12.44
Operating cost per ton	na	19.27	20.61
Operating profit (loss) per ton	na	(6.10)	(8.17)
Net disposal cost per ton[4]	na	9.45	11.46
Net disposal cost per cubic yard[4]	na	2.84	3.44

1. The plant began operation in September 1977.
2. Data shown are for the period January-May 1979; the plant was closed down indefinitely in September 1979.
3. Line items added by Mathtech to reflect the revenues that would have been collected from city collection vehicles had they been assessed the regular tipping fee.
4. The net cost of disposal is taken to be total operating expenditures less revenue from the sale of scrap or steam.

na = Not available.

Sources: Expenses are from unpublished cost accounting records. Tonnages and steam sales are from the 1978 report of the plant and other unpublished operating records. Revenues for 1978 are from the 1978 report; for 1979, revenues are estimated based on the quantity of steam sold and waste processed.

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as the total operating expenditures, less revenue from the sale of scrap and steam. As can be seen, the per cubic yard cost of disposal in the full year 1978 was $2.84, and in the first part of 1979 we estimate that it was $3.44. These costs are considerably higher than the price of landfill disposal, which would require $1.00 per cubic yard in tipping fees, plus an estimated $0.16 per cubic yard in additional transportation costs.

Replacement Cost Analysis--

A somewhat different view of the situation is provided when the income statement is recast with the facility shown at its replacement cost rather than in terms of its historical cost. An income statement using replacement cost would be indicative of the incinerator's financial position if the facility were constructed in the current year. Hence, the replacement cost income statement is the one which other cities should look at if they are in the process of considering a modular incinerator project. In general, if construction costs have escalated at a faster rate than other revenue and expense categories since the original construction period, then the financial picture will appear worse compared to the historical cost basis. If construction costs have escalated at a slower rate, then the financial picture will appear better than the historical cost income statement.

Our best estimate is that the replacement cost for the incinerator facility would be about $1.86 million. This figure was obtained by escalating the original cost of $1.52 million in 1976 to the current year 1979 using the Handy-Whitman index of utility construction costs. Assuming that the financing arrangements would be the same as before (7.5 percent, 20-year revenue bonds), the corresponding annual cost would be $181,000.

When the replacement cost figures are used in the income statement for 1979 (proportionately allocated for five months of operation), a net loss of $88,000, or $10.73 per ton, is obtained. The corresponding net cost of disposal also increases to $115,000, or $14.02 per ton ($4.21 per cubic yard). These figures are larger than those shown in Table 16 because construction costs have risen more rapidly than the general price level. In effect, this means that if North Little Rock were going to invest in resource recovery, it is better to have done so when it did rather than to have waited until 1979.

COMPARISON OF PLANNED VS. ACTUAL RESULTS

North Little Rock's experience with the incinerator project has differed from its expectations in some respects. These differences are summarized briefly below. We should stress that in making these comparisons our intention is simply to identify past problem areas so as to improve future efforts at resource recovery.

Cost of Operations

The expenses forecast in the bond prospectus are quite close to those actually experienced. A comparison between Tables 14 and 16 for the year 1978 (the only complete year available) indicates that actual expenses for operation and maintenance were $168,000, or only 8 percent higher than the

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planned level of $155,000. Assuming that the cost of debt was as anticipated, then the planned capital expense would have been approximately equal to the actual capital expense, or $148,000. Total expenses for the year were thus $316,000, or only 4 percent higher than the planned level of $303,000.

Revenues from Operations

Actual revenues from steam sales were $161,000 in 1978, or 18 percent higher than had been assumed in the bond prospectus ($137,000). The increase was apparently due to a higher price for steam rather than larger steam quantities because the latter appear to have been lower than planned. The annual report for 1978 indicates that anticipated usage was 93,600,000 pounds and actual usage was 67,900,000 pounds. The larger figure is equivalent to 15,000 lb/hr for 24 hours per day, 260 days per year. This is the amount the city is contractually obligated to deliver on demand; however, the factory is not obligated to take this much and clearly has not done so. [1]

Tipping fees from private haulers were considerably lower than planned — $5,000 versus a planned level of $52,000. The overestimate may have been due to an overestimate of the tipping fee per cubic yard that could be commanded. At the incinerator's current price of $1.00 per cubic yard, revenues of $52,000 would require a throughput of about 15,600 tons (52,000 cy) from the private haulers on top of the almost 15,000 tons from the city trucks, or over 30,000 tons throughput in total. The incinerator would have to operate at 85 percent of rated capacity for 360 days per year to achieve this level of processing.

Overall, actual revenues were $166,000 as compared with an estimate of $189,000, or below expectations by only 12 percent.

Operating Problems

At the time of our visit, city officials were generally pleased with the physical performance of the plant and with the services provided by the manufacturer. In the first 21 months between start of operations in September 1977 and our visit in early July 1979, there had been no long-term shutdowns. The plant manager attributed this to the simplicity of the system's design and to the redundancy available from having two completely separate processing lines. [MG]

It was indicated that problems had occasionally arisen from the lack of certain technical skills among the staff. It was felt that good use could be made of specialized skills that would be available with an electrician, a plumber, a boilermaker and a mechanic on the staff. Up to that time, however, it had been difficult to justify hiring such individuals given the size of the operation. At the time of our visit the plant had 11 employees including the manager and a secretary. [MG]

There has also been considerable discontinuity in the plant management. The manager with whom we met had been there about four months and was the fourth manager in 21 months. Representatives of the incinerator manufacturer (Consumat) have provided the plant with on-site managerial assistance,

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particularly in the training of new managers, and a representative was still present for this purpose at the time of our visit. As of the end of 1978, the value of this assistance was estimated to be $208,000. [MG]

The Closure of the Plant

As we have noted previously, the North Little Rock incinerator was closed by the city in September 1979, approximately three months after our visit. It appears that a combination of circumstances led to this decision. As reported to us, the plant had deteriorated rapidly over a two- or three-month period as a result of still another change in plant management and heavy staff turnover, which led to a neglect of routine maintenance and abuse of some of the equipment. An electrical storm also struck the plant, burning out the controls at one end, and repairs made by a local electrician were apparently inconsistent with the system's design. Concurrent with these problems, the mayor of the city resigned, a special election was held, and a new mayor was installed. Shortly after his election, the new mayor toured the facility and decided that conditions had deteriorated to the point that the plant should be closed, which he did on September 25, 1979. The mayor also expressed the opinion that the city did not really have the skills to run the incinerator properly and efficiently, and that he would prefer that a private company take it over. [L,MG]

As of this writing (November 1979), the new mayor is negotiating with the incinerator manufacturer (Consumat) to have the latter operate the plant. The tentative agreement which has been worked out would have the city paying Consumat an amount equal to the city's operating budget for the plant (about $185,000 per year) and receiving in exchange disposal service for the city's waste and any revenues from the sale of steam. Consumat would receive, in addition to the operating payment, all tipping fees collected from private haulers. The city would also be responsible for ash removal and disposal. In the interim, the sale of steam to the factory has been halted and the city has been taking its refuse to a landfill for disposal at a price of $20 per truck (equivalent to $1.00 per cubic yard). [L,MG]

CONCLUSIONS

In this section we attempt to answer three questions: First, is the North Little Rock resource recovery operation economical? Second, if it is not, can this be attributed to the impediments catalogued in the Appendix? And third, what changes would be necessary to overcome these impediments?

Is the Facility Economical?

In the accounting sense of producing revenues in excess of costs, the North Little Rock facility has not been economical. The facility has generated revenues which basically cover the costs of operation and maintenance but not the full cost of interest and principal from the revenue bonds used to finance the facility. The remaining costs are paid for by city residents and commercial establishments from either collection fees or taxes.

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Nor is the facility economical in the broader sense of providing the least costly disposal alternative. The net disposal cost at the facility has ranged between $9.50 and $11.50 per ton, or equivalently $2.80 per cubic yard or more. A landfill about ten miles from the city provides disposal services for $1.00 per cubic yard and the city estimates that the incremental transportation cost to the landfill and back is $0.54 per ton, or equivalently $0.16 per cubic yard.

Financial prospects for the incinerator in the near future are extremely difficult to predict. The facility is now closed for reasons which we have enumerated above. The plant may be reopened in early 1980 under private management pursuant to an agreement between the city and the manufacturer of the incinerator equipment. It appears that the facility should be able to continue to cover the variable costs of operation and maintenance because it had been doing so in 1978 and because it also benefits from one of the more financially attractive steam contracts that we have seen. However, future developments will depend upon the details of the agreement eventually reached and upon other events, speculation about which is beyond the scope of this study.

Another major uncertainty for the facility is the air pollution control situation. The plant at present meets the applicable state standard for particulates. In recent tests, however, it has exceeded the federal standard applicable to large municipal incinerators but, being a small incinerator, is apparently exempt from the standard. Our understanding is that the stricter federal standard applies only to facilities with capacities in excess of 50 tpd, and that the 100-tpd North Little Rock facility is considered to be two 50-tpd incinerators for regulatory purposes because it is constructed as two independent processing lines. If this exemption were to change, the required modifications at the plant would be costly.

What Have Been the Impediments to Economical Operation?

Table 17 lists the various impediments to economical resource recovery catalogued in the Appendix, along with qualitative ratings of how each impediment has affected the experience at North Little Rock. The following discussion summarizes the results presented in the table.

In our judgment, the North Little Rock incinerator has not been economical primarily because land disposal alternatives are still available in the area at a lower price. Although the facility was beginning to develop a reasonably high level of throughput and possessed an attractive steam sales agreement, its net cost of disposal was still more than twice the price of land disposal. While we have no specific evidence that the current low cost of land disposal is due to its being priced below full social cost, this was apparently true in the past* and we expect that it continues to be the case at

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* See the section on Background earlier in the chapter.

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TABLE 17. IMPEDIMENTS TO ECONOMICAL OPERATIONS (NORTH LITTLE ROCK, ARK.)

Impediment	No effect evident	Some effect probable	Large effect probable
Restrict quantity of composition of waste			
Pricing of landfills below full social cost			x
Independent source-separation programs	x		
Returnables policy for bottles and cans	x		
Fragmentation of local government	x		
Restrictions on interstate movement of waste	x		
Seasonal or business cycle fluctuations	x		
Increase initial cost or restrict design			
Inadequacies of available technology	x		
High unit cost for equipment and parts	x		
Limited design experience	x		
Limitations on municipal financing	x		
Low first cost approach to public contracting	x		
Affect cost or efficiency of operations			
Limited operating experience	x		
Limited availability of spare parts	x		
Shortage of required labor skills including supervision		x	
State and federal regulation of air quality	x		
Restrictions on disposal of ash and residue	x		
Limit markets for available products			
Siting restrictions		x	
Franchise restrictions on steam and electric sales	x		
Tax subsidies for virgin materials		x	
Price controls on oil and gas	x		
Lack of futures markets for scrap	x		
Unpriced mining and processing costs	x		
Differential freight rates	x		
Lack of product standards for reclaimed materials	x		
Rate regulation of electric utilities	x		
Restrictions on use of ash, residue and shredded materials	x		
Product labeling restrictions	x		
Government procurement policies	x		

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present, in the sense that strict enforcement of RCRA* provisions relating to landfills would force an increase in the landfill price. If this is the case, then failure to price land disposal in the area at full social cost has been the most significant impediment to economical operation of the incinerator in the past.

The problems which the city has had with labor and management turnover have been discussed earlier. They deserve prominent mention here as a contributing factor in the closure of the plant and thus as an impediment to economical operation. At least in the most recent instance, the inexperience or lack of training among the staff reportedly led to neglect of routine maintenance, abuse of equipment, improper repair procedures, and within a few months, to closure of the plant. Admittedly, in this particular instance the problem was apparently aggravated by some uniquely local politics. However, management turnover had been a problem at the plant from the beginning of operations, and led the original equipment manufacturer to provide over $200,000 in unbilled managerial assistance in order to help keep the plant running smoothly as each new manager was brought on board. The plant finally went under during the tenure of a newly hired fifth manager while the manufacturer's representative was away from the site.

We should also not forget the problem which the city had in siting the incinerator. Recall that the city's first initiative at resource recovery had gotten as far as purchasing land and equipment before being halted, at least in part, because of objections by affected residents and a neighboring town. Not only was it another five years before the current project was undertaken, but the siting problem also left the city with bond payments for land and equipment that were ultimately never used.

Finally, we should mention the existence of tax subsidies for oil and gas production which lower the supply price of oil and natural gas and thus lower the price that can be obtained for steam generated from waste.

What Changes Would Make the Facility Economical?

To illustrate the sensitivity of the incinerator's income statement to various parameters, we carry out below some sample calculations. It should be stressed that the calculations represent order of magnitude estimates and do not take into account a variety of factors that would be considered in a more detailed study of the facility. The sensitivity analysis is conducted with respect to the five months of operation for which data are available in 1979.

Increases in Throughput--

The first question of interest is the level of throughput that would be required for breakeven operation. It turns out that no breakeven level exists for the prices and costs prevailing during 1979. This can be seen as follows. The loss during the first five months was $67,000 which is 67,000 cubic yards worth of tipping fees, or equivalently about 20,000 tons. The average processing rate at the plant during this period was 82 tpd for 100 days. If the plant had run at full capacity during this period, it could have processed only an additional (100 tpd) x (150 days) - (82 tpd) x (100 days) = 6800 tons, or about one-third of the amount required. Nor would the higher level of throughput have resulted in additional steam revenues because the plant was already supplying more than the factory needed. Increased throughput alone would thus not be sufficient to provide breakeven operation.

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* The Resource Conservation and Recovery Act of 1976.

Increase in Landfill Prices--

If the incinerator could increase its tipping fee by $8.17 per ton ($2.44/cy), its projected loss for 1979 would be erased. An increase of this size could be sustained without losing private haulers to the landfill if the latter had to increase its price by the same dollar amount. An increase of this size would be about (100)(2.45)/(1.00) = 245 percent. While strict enforcement of RCRA might produce large increases in landfill prices, it is unlikely that the increases would be as large as this.

Increase in Oil and Gas Prices--

An increase in steam revenues of $67,000 would also erase the deficit projected for 1979. To achieve this increase without increasing the quantity of steam sold would require an increase in the price of steam and thus in the price of oil and natural gas to which the steam price is pegged. An increase of $67,000 would require a steam price increase of (100)(67,000)/(75,000) = 89 percent. Because of the way the steam purchase agreement is formulated, the corresponding increase that would be required in the price of oil and natural gas ranges from 89/1.5 = 59 percent to 89/1.05 = 85 percent. Increases of this size are possible, given the behavior of oil prices since the beginning of 1979, but increases of smaller magnitude are more likely in the near future. An alternative possibility that might accomplish the same result would be the addition of a second steam customer, if one could be found.

Combinations of Changes--

We have not explicitly considered above the possibility that several factors could be changed simultaneously. We have looked only at individual factors and found that a change in any one factor will probably be insufficient to bring about breakeven operation. The analyses above suggest that a combination of changes -- higher throughput, higher landfill tipping fees, and especially, higher oil prices -- may be necessary. Given strict enforcement of RCRA and continued domination of the energy markets by a foreign cartel, then these changes will most likely come about.

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ACKNOWLEDGMENTS

We are grateful to Mr. Ken Minyard, former plant manager; Mr. Gene Green, Consumat representative; Mr. Charles Wrobleski, former North Little Rock city councilman; and Mayor Laman, City of North Little Rock, who provided information and material in addition to the references cited above. Reference to information contributed by Messrs. Minyard and Green is denoted by the letters "MG" appearing in the text; "W" denotes references to information contributed by Mr. Wrobleski; and "L" denotes references to information contributed by Mayor Laman.

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SECTION 6

MONMOUTH COUNTY, NEW JERSEY

SUMMARY

Monmouth County, New Jersey, owns and operates a reclamation center which shreds municipal solid waste and extracts ferrous metal prior to sanitary landfilling. It was originally hoped that the capacity for producing refuse-derived fuel (RDF) could be added to the facility at some future date, but the absence of a viable market for RDF has prevented this. It appears that the county was encouraged by state and federal authorities to believe that sophisticated resource recovery operations would be both cost-effective and necessary, but these earlier hopes have been disappointed.

BACKGROUND

Area Characteristics

Monmouth County is a rural and suburban region at the northern end of New Jersey's Atlantic coast. A majority of the county's population of some 500,000 is concentrated along the seacoast; the county seat of Freehold is located about 12 miles inland, near the geographical center of the county. The county includes 53 municipalities; the largest city, Middletown, has a population of 64,000, and none of the others exceeds 35,000. Many of the coastal towns are resort areas whose populations and quantities of waste increase during the summer.

Historical Methods for Solid Waste Disposal

Collection of solid waste in Monmouth County is generally organized at the municipal level, while disposal is gradually assuming a more regional orientation. It is estimated that in 1977-78 annual residential waste collection in the county amounted to 359,000 tons, or 984 tons per calendar day, and that this accounted for 51 percent of total waste collection. Industrial waste accounts for another 21 percent, while commercial (12 percent), institutional (7 percent), and non-residential municipal waste (7 percent), account for most of the remainder. Ten municipalities (producing 22 percent of the waste), mainly in rural areas, have residential waste collection by private collectors, 22 municipalities (producing 41 percent of the waste) have municipal collection of residential waste, and 21 municipalities have contract collection of residential waste. [2,3,4]*

Most of the solid waste generated in Monmouth County is disposed of in landfills. For example, looking at residential waste volumes, we find that 79 percent is landfilled, 3 percent is incinerated, and the remaining 18 percent goes to the Monmouth County Reclamation Center (MCRC). The ten landfills receiving Monmouth County waste include six within the county, two of which are municipal landfills, and four others outside the county.** The largest landfills are privately owned and operated and charge disposal fees ranging from $.75 to $1.50 per cubic yard. [2,3,4]

Prior to 1970, disposal service in New Jersey was primarily the responsibility of municipalities and private firms. Legislation enacted by the state in 1970 and 1975 granted new authority and responsibility to county governments and designated counties as disposal regions for purposes of solid waste management planning. Under the new legislation, counties are authorized to plan, acquire, finance, construct and operate solid waste management systems. The vehicle for county participation can be a county utility, a county improvement authority, or direct involvement by the county itself. The choice among these various institutional forms will depend in large part on whether the project is to be financed with revenue bonds or general obligation bonds. [4]

Initial Planning for the Facility

The "County Solid Waste Disposal Financing Law" enacted by the state in 1970 set the stage for direct county involvement in solid waste disposal. The law was motivated in large part by the increasingly difficult problem of siting disposal facilities. Acting under this authority, the Monmouth County Board of Chosen Freeholders (the county's governing body) began the design of a joint sanitary landfill and solid waste processing facility in 1972. The site selected for the facility was in the east central part of the county about six miles from the coast. The site includes 104 acres developed as a sanitary landfill in 1972 and an additional 166 acres available for development at a later date. [4]

The initial motivation for including a processing facility on the site was to extend the life of the associated landfills. This was to be accomplished by shredding the incoming waste in order to reduce its volume. The landfill application was approved by the state Department of Environmental Protection in 1972 and the design work for the processing facility began at that time. [4,G]

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* The numbers in brackets refer to references listed at the end of this chapter.

** This list excludes one private landfill which accepts only demolition and construction waste, and two landfills located on military bases for exclusive use of the bases.

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Construction of the processing facility began in July 1974 and was completed in October 1976. The capital cost of the facility, $3,600,000, was financed through federal revenue sharing funds. [4]

In 1974 at about the same time that construction of the center was begun, Army authorities at Fort Monmouth, located five miles north of the center, expressed an interest in identifying sources of alternative fuels to fire the base's heating system. The price of fuel oil used by the base had recently risen from 12 cents per gallon to 35 cents per gallon. The Army subsequently produced a study proposing to modify the reclamation center for production of RDF for use at Fort Monmouth. [1,G]

The county was apparently receptive to the idea of incorporating energy recovery at the center. In addition, the climate was right for resource recovery since both the state and federal governments were encouraging recovery activity. The state's position was stated formally in legislation subsequently passed in 1975 — the New Jersey Solid Waste Management Act — which makes each of New Jersey's 21 counties a Solid Waste Management District responsible for developing and implementing a solid waste management plan. One objective identified by the state Department of Environmental Protection for inclusion in these plans is the maximum practicable use of resource recovery including low and high technology systems. [3,4]

The Fort Monmouth proposal was not carried out, and county authorities are uncertain about the reason. The economics were attractive from both the county's and the Army's point of view.* The county has also explored other markets for RDF and has been unable to locate any. In particular, electric utilities have expressed a disinterest in buying RDF. [G]

OPERATION OF THE FACILITY

Operation of the facility is under the direction of a plant superintendent who has responsibility for day-to-day management. The plant superintendent reports to the county administrator within whose office resides the responsibility for longer-range planning, including preparation of the state-required solid waste management plan for the county. The county administrator and the director of the county planning board share the responsibility for marketing of recovered products. All responsibility for solid waste collection, as we noted earlier, is left to the individual municipalities. [G]

Plant Description

Collection trucks entering the reclamation center are weighed on a platform scale with automatic recording equipment and proceed to a fully enclosed tipping area where front-end loaders push waste onto conveyor bents.

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* This is discussed further in a later section.

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The conveyors deliver waste to either of two separate processing systems, each consisting of a 1000-horsepower vertical grinder which reduces waste to three-inch particle size, a drum magnet to separate ferrous metal, and a compactor to reduce volume for landfilling. Compacted waste is then transported to the adjacent landfill. After shredding and compaction, the waste has less tendency to blow or attract birds and vermin, so it can be filled without daily cover. Consequently, the landfill has been granted a variance from sanitary landfill regulations and requires a six-inch cover once a week rather than daily. [2,G]

The facility is open for vehicles delivering waste six days a week between 7:00 am and 3:30 pm. The shredders are operated about five hours per day, after which time they are shut down for routine daily maintenance. Maintenance requires approximately one shift per day and is now done on overtime. The plant staff of 16 performs all the required maintenance except for specialized jobs such as equipment transmission overhauls. In practice, each shredder is operated and then shut down for heavy maintenance on a cycle of five-six weeks. The full processing load is then carried by the other shredder. [G]

The plant superintendent has been quite pleased with the performance of the shredder equipment. Although each shredder has a rated capacity of 40 tons per hour (tph), they are constantly operated at 65 tph and can handle up to 80 tph. In addition, the shredding operation has had to be completely shut down for only four days since the plant was opened in October 1976. On the other hand, replacement parts are considered expensive, a condition aggravated by the fact that the manufacturer (Carborundum) no longer makes this particular line of shredder. [G]

Environmental restrictions have not generally presented the center with problems. The groundwater level is between three and five feet, and the landfill is lined with soil with high clay content. However, there is still some uncertainty as to whether the fill will be required to have a plastic liner to avoid water pollution. The site is in a rural area adjacent to an older private landfill and a Naval ammunition depot. There have been no complaints about noise or odors from the plant, although residents along the access road have complained about increased traffic from collection trucks. The present landfill is expected to reach capacity around 1985, by which time the remainder of the site will be developed for filling. After the active life of the landfill operation is over, a county recreational area is planned for the site. [G]

Materials Recovery

Ferrous metal is the only recovered product bringing significant revenue to the center. Large pieces of aluminum (e.g., lawn chairs) are sometimes hand-separated and sold to the same scrap metal dealers who buy the ferrous metal. During the first year of its operation the center had a contract to sell ferrous metal to a detinning plant in Delaware for $20 per ton, but this source of revenue dried up when the buyer went bankrupt. Ferrous metal is now

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sold to scrap metal dealers for $6 per ton. The level of contaminants in the recovered metal is about 1.5 percent. [G]

Tires are separately shredded, partly in order to reduce volume for landfilling and partly because it is felt that a market for recycled rubber may become available. However, no buyer has been found for the rubber which is thus being stockpiled. Likewise, the sale of glass, which would require further processing, has been considered but no market has been found. The glass companies have not been interested in glass of mixed colors. [G]

Energy Recovery

As we noted earlier, the county has been interested in pursuing energy recovery at the center. In fact, the reclamation center has been constructed so that additional processing equipment can be added at a later date for use in producing refuse-derived fuel (RDF). The center came closest to developing an energy recovery capability in 1974-75 when Army authorities at nearby Fort Monmouth expressed an interest in purchasing RDF from the center to replace the fuel oil then used at the base.

The largest of Fort Monmouth's three boiler plants was originally designed for possible conversion to coal, although it has always fired No. 6 fuel oil. If converted, it would provide a market for 27,000 tons of RDF per year. The cost of converting the boiler for RDF was estimated at $1,738,300 (1975), including ash and fuel handling equipment, structures, boiler modification and air pollution controls. Amortized over 20 years at 10 percent interest, the annual cost was figured at $204,200, plus incremental operation and maintenance costs of $150,000 per year. Transport of the RDF from the center to the storage bin was estimated to require an investment of $101,500 in equipment, or $19,000 amortized over eight years, at 10 percent interest plus annual operating costs of $90,000. The total annual cost of using RDF at the fort was thus estimated to be $463,800. In return for its investment, Fort Monmouth would realize annual fuel savings of $895,000, and refuse haul and dump savings of $90,000. Net annual savings were thus estimated at over half a million dollars, or $19.30 per ton of RDF burned. The fort could thus have paid up to $19.30 per ton for RDF. [8]

Sale of RDF to Fort Monmouth would have required the county to add air classifiers, compactors and handling equipment to the facility at an estimated cost of $979,000 (1975). The annual operating and maintenance cost of this addition was estimated at $59,400. Amortizing the capital cost over ten years at 10 percent interest would mean an annual capital cost of $159,500 to the county, for a total annual cost of $218,900 at capacity RDF production. If Fort Monmouth were the only RDF customer, the annual costs were figured at $193,500, or $7.17 per ton of RDF sold. The large difference between the breakeven selling price of $7.17 per ton and the breakeven buying price of $19.30 per ton indicates that the proposal could have been very profitable on both sides. In addition, it was estimated that the facility could produce 70,000 tons of RDF if the center processed waste at a rate of 400 tpd or 100,000 tons per year. Thus the center would have the capability to sell an additional 43,000 tons of RDF per year if additional buyers could be found.

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Furthermore, these figures do not reflect savings from extending the landfill life, since any volumes shipped as RDF would not have to be landfilled. [8]

Despite the attractiveness of the proposal to both parties, no implementation occurred. It is speculated that budgetary constraints prevented the fort from undertaking the required capital expenditures.

FINANCIAL ANALYSIS

Sources of Revenue

Although some revenue is derived from the sale of recovered material, the center's major source of revenue is tipping fees. Haulers delivering up to 700 tons of mixed waste per year are charged $5.75 per ton; haulers delivering more than 700 tons annually are charged $4.00 per ton. Construction and demolition waste, which cannot be reduced by shredding, is accepted at $6.00 per ton, and tires are accepted for $1.00 each. [G]

Price notwithstanding, haulers not bound by contract to particular landfills are said to prefer the reclamation center in two circumstances: First, in bad weather the reclamation center is preferable because it provides better access roads, thus saving both hauling time and vehicle wear. And second, since the reclamation center's tipping fee is based on tonnage rather than volume, haulers prefer to deliver less dense loads to the center and more dense loads to private landfills. In particular, construction and demolition waste is not taken to the center. Based on data from 1977 and 1978, waste delivered to the center has an average density of 0.196 tons/cy, which at $4 per ton is equivalent to a $0.79/cy tipping fee, one comparable to fees charged by landfills. [2,G]

Statements of Income

Using annual reports which the center submits to the state public utility commission, we have constructed income statements for the center for the years 1976 to 1978, and estimates for 1979. The figures shown in subsequent pages represent our best judgment as to the center's financial history. In examining these figures the reader should nonetheless keep the following items in mind. First, as noted previously, the center is a joint shredding and landfilling operation. The expenditure data are available only for the overall operation and thus do not permit calculation of the incremental cost of shredding.

Second, as noted previously, the capital cost of the center was paid for with revenue sharing funds rather than revenue bonds. If the latter had been used, then the income statement for the center would include payments for interest and principal. Instead, however, the annual reports include only a depreciation charge. To provide for greater comparability with resource recovery projects in other communities, and to reflect the opportunity cost of having used the revenue sharing funds for this purpose, we have added an implicit interest expense to the expenditure accounts. The interest expense has been calculated as 6 percent of the remaining book value of the facility.

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Conventional Analysis--

Key financial and operating data for the center are shown in Table 18. Recall that the center began operations in October 1976, so results for that year are atypical. The other years show a steady increase in the quantity of waste processed, which suggests that the center is attracting more and more waste from other facilities. At the time of our visit in June 1979 the facility was receiving waste from 19 municipalities, compared to 14 in August 1978. [G]

An overview of the financial results indicates that the incinerator has consistently operated at a loss, although the size of that loss is shrinking over time. Revenues are not yet sufficient to cover all variable costs, nor thus to contribute towards payments of interest and principal if such payments had been required.

Of particular interest is the next to last line in Table 18, which shows the per ton net cost of disposal. The net cost of disposal can be defined as total operating expenditures, less revenues from the sale of scrap and energy. As can be seen, the per ton cost of disposal has varied between about $12 and $28. On a per cubic yard basis, the cost has varied between about $2.40 and $5.50. At $2.40 per cubic yard, the center is experiencing disposal costs of about twice the going price at competing landfills. These rates reflect the incorporation of charges for interest and principal. If the latter are removed from the calculation, the costs fall to $7.28 per ton and $1.46 per cubic yard. The latter is at the upper range of the prices at competing landfills.

One may be tempted to argue that it is unfair to compare the cost per cubic yard at the center with the cost at nearby landfills because in doing so it ignores the value of the volume reduction that occurs and other benefits. This temptation should be resisted. It can be argued that all of the benefits of the shredding operation will indeed be reflected in the financial statement and hence that the cost per cubic yard comparison is valid. The argument can be briefly summarized as follows. First, since shredding reduces the volume of waste, then a joint shredding/landfill operation can process the same tonnage as a normal landfill but dispose of the waste in a smaller land area. Thus the joint operation can provide the same landfill capacity on a smaller site and hence realize savings in the costs of land ownership. These savings will, however, be reflected directly on the income statement in the form of lower debt and interest payments or land rental costs. Second, savings in operating costs may also be realized with the joint shredding/landfill operation. Because the site is smaller and the volume per ton is smaller, it may be possible to use fewer men, fewer pieces of equipment, or smaller equipment. Also, the shredding may reduce the costs of providing cover, of controlling vermin and insects, and of controlling fires because the shredded material is more compact and inert. Yet all of these are savings in operating costs and as such will also be reflected directly on the income statement. Hence, all of the benefits usually mentioned in connection with joint shredding/landfill operations would be reflected on the income statement for the joint operation, thus permitting direct comparisons with the standard landfill operation.

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TABLE 18. OPERATING DATA, MONMOUTH COUNTY RECLAMATION CENTER
(All dollar amounts in thousands of dollars, except per ton amounts)

	1976[1]	1977	1978	1979[2]
Operating revenues				
Tipping fees	1	138	253	375
Sale of materials	0	8	3	3
Total operating revenue	1	146	255	378
Operating expenditures				
Salaries and wages[3]		231	259	300
Fringes[4]		31	40	45
Parts and maintenance		58	73	90
Utilities	333	45	58	75
Insurance		34	35	40
Other operating expenditures		35	41	46
General and administrative		54	62	70
Taxes	7	13	17	21
Depreciation	58	239	240	240
Interest foregone[5]	58	227	212	198
Total operating expenditures	456	968	1,035	1,125
Operating profit (loss)	(456)	(822)	(780)	(747)
Net disposal cost[6]	456	960	1,033	1,122
Refuse received (tons)	na	33,780	65,304	93,900
(10^3 cubic yard)		175	329	470
Refuse shredded (tons)	na	22,639	43,826	62,900
Ferrous recovered (tons)	na	605	790	380
Operating revenue per ton	na	4.32	3.90	4.03
Operating cost per ton	na	28.66	15.85	11.98
Operating profit (loss) per ton	na	(24.33)	(11.94)	(7.96)
Net disposal cost per ton received[6]	na	28.42	15.82	11.95
Net disposal cost per cubic yard received[6]	na	5.49	3.14	2.39

1. Construction completed in October 1976; expenses not itemized for that year.
2. Figures for 1979 are projections by Mathtech based on tonnage processed through May 1979.
3. Excludes supervisory labor, included in General and Administrative.
4. Includes FICA, SUI, retirement and employee welfare.
5. Line item added by Mathtech to reflect opportunity cost of using revenue sharing funds; calculated as 6 percent of remaining book value.
6. The net cost of disposal is taken to be total operating expenditures less revenue from the sale of recovered scrap or energy.

na = Not available.

Sources: For the years 1976 to 1978, Annual Report of the Center to the state utility commission.

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The importance of the center, and also its financial picture, are destined to be strengthened by several factors operating in its favor. First, the largest landfill in the area, in terms of county waste taken, is coming near to the end of its useful life. This landfill (Global), which takes 23 percent of the county's residential waste, is estimated to have less than five years of life remaining. With a price of 75 cents per cubic yard, this landfill has been a formidable competitor.

Second, the next three largest landfills in the area either have serious environmental problems or have been repeatedly cited for violation of state regulations concerning operating practices. One has groundwater very near the surface, another has been repeatedly cited for serious leachate problems, and the third has been repeatedly cited for inadequate cover. As the state clamps down on these landfills, or closes some of them as recommended by the county solid waste advisory committee, it will either increase the price they must charge or eliminate them as competitors. Elimination of the cut-rate competition, or an increase in their costs, would enable the center to increase its tipping fees. There is also the possibility that the production and sale of refuse-derived fuel may again surface as a potential revenue source. [4]

Replacement Cost Analysis—

A somewhat different view of the situation is provided when the income statement is recast with the facility shown at its replacement cost rather than in terms of its historical cost. An income statement using replacement cost would be indicative of the center's financial position if the facility were constructed in the current year. Hence, the replacement cost income statement is the one which other cities should look at if they are in the process of considering a joint shredding/landfill project. In general, if construction costs have escalated at a faster rate than other revenue and expense categories since the original construction period, then the financial picture will appear worse compared to the historical cost basis. If construction costs have escalated at a slower rate, then the financial picture will appear better than the historical cost income statement.

Our best estimate is that the replacement cost for the center would be about $5.3 million. This figure was obtained by escalating the original cost of $3.6 million in 1974 to the current year 1979 using the Handy-Whitman index of utility construction costs. Assuming that this amount would be amortized over 20 years and that an interest rate of 7 percent would now be required, the annual cost would be $0.50 million. When this figure is used in the estimated income statement for 1979, a net loss of $0.81 million, or $8.63 per ton, is obtained. The corresponding net cost of disposal also increases to $1.18 million, or $12.56 per ton. These figures are slightly larger than those shown in Table 18 because construction costs have risen more rapidly than the general price level, and because interest rates are higher. In effect, this means that if Monmouth County were going to build the reclamation center, it is better to have done so when it did rather than to have waited until 1979.

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COMPARISON OF PLANNED VS. ACTUAL RESULTS

Monmouth County's experience with the reclamation center project has differed from its expectations in some respects. Perhaps the foremost of these is the county's disappointing experience with energy and materials recovery. There is a feeling among county officials with whom we talked that in taking steps to create a resource recovery facility several years ago, the county was following suggestions from state and federal officials that resource recovery be pursued (materials recovery in the early 1970's, and energy recovery more recently). While acknowledging the technical and financial assistance of other levels of government, these officials seemed disappointed that the state and federal governments have not been of assistance in the one way that now seems most crucial -- identifying and promoting markets for RDF and scrap. Indeed, in the one instance where the county came closest to finding a customer for RDF -- a federal army base -- the government backed away, even though the financial arrangements would have been very attractive for both sides.

Officials in Monmouth County also pointed out an unexpected way in which state and federal regulation of air quality have hindered resource recovery, particularly in the east. They note that restrictions on SO_x and particulate emissions led most utilities and industrial plants in the 1960's and early 1970's to convert coal-fired equipment to oil or natural gas and to avoid installation of new coal-fired equipment. Consequently, the current population of coal-fired equipment in the east is proportionately quite small. Hence, the market for RDF is limited because there is little equipment available for co-firing of RDF and coal or conversion from coal to RDF.

CONCLUSIONS

In this section we attempt to answer three questions: First, is the Monmouth County Reclamation Center economical? Second, if it is not, can this be attributed to the impediments catalogued in the Appendix? And third, what changes would be necessary to overcome these impediments?

Is the Facility Economical?

In the accounting sense of producing revenues in excess of costs, the center is not at present economical. Even if we remove depreciation and interest charges from the income statement, to reflect the fact that the facility was financed with revenue sharing funds, the revenues are still not sufficient to cover the remaining variable costs. The difference is paid for by county taxpayers.

Nor is the facility economical in the broader sense of providing the least costly disposal alternative. The net cost of disposal at the center, including tipping fees and indirect subsidies, is about twice the rate charged

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by most landfills in the county.* This is true despite relatively reliable performance from the shredders and a high level of throughput projected for the most recent year.

Financial prospects for the center in the 1980's are difficult to predict. The rapid revenue growth which the center has been experiencing will begin to taper off now that the facility is beginning to reach design capacity; some additional growth may be possible with the addition of a Sunday processing shift. Variable costs, on the other hand, are growing almost as rapidly so that it seems unlikely the center will be able to cover its variable costs without either an increase in the tipping fee or location of a market for RDF.

It is possible that the ability to command a higher tipping fee may be realized in the near future. The largest landfill serving the county will reach capacity within five years; the next three largest landfills either have serious environmental problems or have been repeatedly cited by the state for operating violations. The competition may thus begin to thin out and those remaining may begin to experience higher operating costs. At least some of the long-term trends then appear to be operating in the center's favor. However, speculation on whether these events will actually occur, and on what their financial implications are likely to be, is beyond the scope of this study.

What Have Been the Impediments to Economical Operation?

Table 19 lists the various impediments to economical resource recovery catalogued in the Appendix, along with qualitative ratings of how each impediment has affected the experience at Monmouth County. The following discussion summarizes the results presented in the table.

In our judgment, the financial situation at the reclamation center results primarily from the center's inability to command a higher tipping fee for waste disposal. The center has followed the policy of pricing its disposal service at a level which is competitive with the landfills in the county. This has enabled the center to achieve high levels of throughput in a comparatively short time, but it has also resulted in large operating losses because the price is well below the center's average disposal cost.

The center finds it difficult to compete with the other landfills because the latter appear to be pricing their disposal service below the full social cost. As we have noted previously, at least two of the four largest landfills in the area are the source of considerable negative environmental impact. Each has been cited by the state for repeated violations ranging from excessive litter and inadequate cover to leachate problems. We expect,

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* The cost is nearly comparable, however, if interest and depreciation charges are removed.

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TABLE 19. IMPEDIMENTS TO ECONOMICAL OPERATIONS (MONMOUTH COUNTY, N.J.)

Impediment	No effect evident	Some effect probable	Large effect probable
Restrict quantity or composition of waste			
Pricing of landfills below full social cost			x
Independent source-separation programs	x		
Returnables policy for bottles and cans	x		
Fragmentation of local government	x		
Restrictions on interstate movement of waste	x		
Seasonal or business cycle fluctuations	x		
Increase initial cost or restrict design			
Inadequacies of available technology	x		
High unit cost for equipment and parts	x		
Limited design experience	x		
Limitation on municipal financing	x		
Low first cost approach to public contracting	x		
Affect cost or efficiency of operations			
Limited operating experience	x		
Limited availability of spare parts		x	
Shortage of required labor skills including supervision	x		
State and federal regulation of air quality		x	
Restrictions on disposal of ash and residue	x		
Limit markets for available products			
Siting restrictions	x		
Franchise restrictions on steam and electric sales	x		
Tax subsidies for virgin materials		x	
Price controls on oil and gas		x	
Lack of futures markets for scrap	x		
Unpriced mining and processing costs	x		
Differential freight rates	x		
Lack of product standards for reclaimed materials	x		
Rate regulation of electric utilities	x		
Restrictions on use of ash, residue and shredded materials	x		
Product labeling restrictions	x		
Government procurement policies	x		

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therefore, that their price does not reflect the full social cost of disposal and that strict enforcement of RCRA* provisions relating to landfills would eliminate much of the competitive advantage that the landfills now enjoy. If this is the case, then failure to price land disposal in the area at full social cost has been the most significant impediment to economical operation of the center in the past.

It also seems clear from the Army's analysis of the potential for RDF sales by the center to nearby Fort Monmouth that the center's economic position would be greatly improved if a customer for RDF could be found. The analysis (in 1975) showed that the center could operate a breakeven RDF business at a selling price of $7.17 per ton ($0.72/MBtu) at a time when residual oil was selling in the area for $0.35 per gallon ($2.33/MBtu). County officials attribute the limited market for RDF to air quality regulations which have limited the use of coal on the east coast and thus limited the possibilities for co-firing of coal and RDF or conversion from coal to RDF. One could presumably add to this the existence of tax subsidies and price controls for oil and natural gas which hold down oil and gas prices and thus reduce the financial incentive for conversion of oil- and gas-firing to RDF and coal.

The increased cost of replacement parts due in part to the fact that the manufacturer no longer produces the line of shredder which the facility uses has probably had some effect, although its extent is difficult to measure. From 1977 to 1979, parts and maintenance costs increased by 55 percent, an increase exceeded only by that of utilities and taxes. If parts and maintenance costs had increased at the same rate as all other variable costs (35 percent), the operating cost and net disposal cost would be about $0.13 per ton less than at present.

The bankruptcy of the detinning plant in Delaware which previously bought ferrous scrap has led to some loss of revenue. If the county had continued to sell scrap for $20 per ton in 1978 and 1979 instead of $6 per ton, it would have lowered the operating loss and net disposal cost per ton by about $0.17 and $0.06 per ton in the two years, respectively. The loss of revenue from sale of materials is quite small in comparison to the potential value of recovered energy, however.

What Changes Would Make the Facility Economical?

To illustrate the sensitivity of the center's income statement to various parameters, we carry out below some sample calculations. It should be stressed that the calculations represent order of magnitude estimates and do not take into account a variety of factors that would be considered in a more detailed study of the facility. The sensitivity analysis is conducted with respect to the financial results projected for 1979.

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* The Resource Conservation and Recovery Act of 1976.

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Increases in Throughput--

The first question of interest is the level of throughput that would be required for breakeven operation. It turns out that no breakeven level exists for the prices and costs prevailing during fiscal 1979. This conclusion can be seen as follows. First, the maximum throughput which the center could reasonably hope to obtain is about 146,000 tons per year. This would be based on operation at 100 percent of the 400-tpd capacity for 365 days per year. Revenues from tipping fees at 146,000 tons would be ($4 x 146,000) = $584,000; scrap sales might add $5-6,000 more, bringing the total to $590,000. Expenses at this level of throughput would be at least as large as projected for 1979, or $687,000 in direct expenses plus $438,000 in depreciation and foregone interest. The direct expenses alone would exceed available revenues, implying that breakeven operation could not be brought about through increases in throughput alone.

Increases in Landfill Prices--

If the center could increase its tipping fee by $7.96 per ton ($3.29/ton if depreciation and foregone interest are excluded), then its projected loss for 1979 would be erased. An increase of this size could be sustained without losing waste to the competing landfills if the latter were to increase their prices by the equivalent dollar amount. At the center's ratio of 0.2 tons per cubic yard, the equivalent dollar increase would be 0.2 x $7.96 = $1.59 per cubic yard ($0.66/cy with depreciation and interest excluded). For the average landfill in the area which charges about $0.80 per cubic yard, this would represent an increase of almost 200 percent (83 percent without interest and depreciation). While strict enforcement of RCRA might produce large increases in landfill prices, it is unlikely that the increases would be as large as this.

Combinations of Changes--

We have not explicitly considered above the possibility that both factors could be changed simultaneously. We have looked only at individual factors and found that a change in either one alone will probably not be sufficient to bring about breakeven operation. Indeed, the analyses above suggest that a combination of changes -- higher throughput and higher landfill tipping fees -- may be necessary. The prospects look reasonably good, however, for this combination of changes to come about.

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ACKNOWLEDGMENTS

We are grateful to Mr. John Gray, Superintendent of the Monmouth County Reclamation Center, who provided information and material in addition to the references cited above. Reference to information contributed by Mr. Gray and his staff during our interview is denoted by the letter "G" appearing in the text.

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SECTION 7

NEW CASTLE COUNTY, DELAWARE

SUMMARY

AENCO, formerly the All-American Environmental Control Corp., of New Castle, Delaware, built and operates a facility owned by New Castle County for shredding mixed municipal waste and recovering materials. The facility was constructed in 1971-72 to extend the life of the county landfill and to provide the nucleus for further resource recovery activities. AENCO has been successful in the limited operations undertaken and claims with some justification to be the only company in the resource recovery industry that does not lose money operating a plant on a fixed-price basis. New Castle County has benefited from the extension to the life of its landfill, although the value of this benefit is difficult to estimate. Resource recovery has so far been limited to ferrous metal recovery, and other recovery initiatives have been frustrated by actions at other levels of government.

BACKGROUND

Area Characteristics

New Castle County includes the northern third of the state of Delaware and has a population of about 400,000 (1975). The county has experienced modest population growth during the 1970's following substantial growth in the previous decade. One-quarter of the county's residents live in the cities of Wilmington (76,000) and Newark (27,000), and the remainder reside in towns and unincorporated suburban areas of the county. The employment base of the county includes manufacturing (33 percent), wholesale and retail trade (23 percent), and government (9 percent), with the remainder primarily in service industries, utilities, and construction.

Historical Methods for Solid Waste Disposal

The cities of Wilmington and Newark have municipal solid waste collection systems, and until 1971 also operated their own landfills. Other areas of the county depend primarily on private haulers, and until the late 1960's most of this waste was taken to about ten private landfills in various parts of the county. Since the early 1970's, waste disposal has been carried out primarily

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by the county, which had also provided landfill services in previous years. [2]

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Initial Planning for the Facility

As in other communities, the county's interest in resource recovery was originally stimulated by a shortage of acceptable landfill sites, but unfortunate experiences with environmental pollution have apparently contributed to this interest as well. In 1971, leachate from a landfill which the county had operated at Llangollen, Delaware between 1960 and 1968 was discovered to be polluting the local water supply. Operating costs at the landfill had been $2.50 per ton, but it has been estimated that the cost of repairing leachate damage may push the final cost of disposal to $20.00 per ton. In 1969, the county opened another landfill with an expected life of five years, but increased quantities of waste cut the actual life of the landfill to two and one-half years. [2,3]

The present 187-acre landfill site located near the Delaware River at the foot of the Delaware Memorial Bridge was acquired by the city of Wilmington in 1971. A clay berm and a base of impervious mud are said to make the site particularly suitable for landfill use. About 156 acres of the site were thought to be available for disposal purposes, although environmental restrictions have since reduced this to 110 acres. It was estimated that if the landfill took all waste generated in the county, it would receive about 300,000 tons per year and meet the disposal requirements of the county for about ten years if no action were taken to extend its life. The city leased the site to the county under the conditions that the county accept all waste from the city and also initiate shredding operations to extend the life of the fill. [2,N]

Although the building of a shredding plant was thus a precondition of the county's use of the city of Wilmington's landfill site, the county was apparently sympathetic to the shredding concept as a result of its own investigations. County officials and engineers had surveyed disposal approaches in several other parts of the country and concluded that grinding (shredding) of the refuse offered the most promise. The alternatives considered apparently included composting, standard sanitary landfilling, sanitary landfilling with shredding, and incineration. It was felt that shredding would reduce the waste volume and the requirements for cover material so that the overall cost of disposal would not increase unreasonably. Compared to the other alternatives considered, shredding was also seen as having the advantage of offering the opportunity for recovery of material. [3]

Financing and Construction of the Facility

The contract to build the shredding facility was awarded to the All-American Environmental Control Corp. (AENCO), then a subsidiary of the All-

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American Engineering Company of Wilmington. AENCO has subsequently been acquired by Cargill, a Minneapolis grain shipping and warehousing company with diversified interests. AENCO began construction of the shredding facility in September 1971 and completed construction one year later. Shakedown tests were conducted and modifications were made to the plant between October and December 1972, and during an extension of the shakedown period until March 1973, at which time the plant was accepted by the county. [2,N]

AENCO estimates that the total construction cost of the shredding plant was about $2.4 million. This amount includes: $1,995,000 which represents the original construction cost and the price at which the county purchased the plant from AENCO; another $300,000 in unreimbursed modifications made by AENCO during the October to March shakedown period; and an additional $80,000 in modifications paid for by the county and carried out by AENCO following acceptance of the plant in March of 1973. [2,N]

The purchase of the shredding plant was financed by an issue of bonds in 1973 in the amount of $2,990,000. The remainder of the bond issue was used for site development and equipment acquisition related to the shredding/landfill facility. Additional capital improvements were carried out at the facility in subsequent years, including: $1 million in 1975-76 for leachate monitoring and control at the landfill; road construction at the landfill; and other improvements. Following the county's usual practice, these later improvements were paid for initially out of general county funds, and later refunded with an issue of bonds. An issue of $4 million in bonds was sold in 1977 for this purpose, and another $850,000 was sold in 1978 for financing the acquisition of land adjacent to the landfill for future expansion. [F]

OPERATION OF THE FACILITY

AENCO operates the plant under contract with the county and has been doing so since December 26, 1972. Under the terms of the agreement, the county operates the landfill, the scales, and the rolling stock, while AENCO operates the adjacent shredding facility. Administration of the landfill and the contract between AENCO and the county is the responsibility of the New Castle County Department of Public Works. [2,4,N]

Plant Description

At the shredding plant, trucks deliver refuse directly onto one of two 80-foot receiving pit conveyors or onto a concrete receiving pad from which it is bulldozed onto the conveyors. From the receiving conveyors, the waste is discharged onto one of two feed conveyors which transport waste to the shredder lines. Each shredder line consists of two Gruendler model 50XE shredders arranged in series which have been equipped with 900-hp motors to upgrade their capacity to about 70 tph each (vs. 50 tph originally). The shredders pulverize waste to an average particle dimension of two inches. Shredded waste is then discharged onto a single discharge conveyor system which can be maneuvered to deposit shredded waste over a large area of the landfill. [3,4]

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Prior to dumping the shredded waste, the secondary conveyor passes under a belt electromagnet which separates out the ferrous metals. The ferrous metal is shunted to another conveyor, cleaned of most contaminants in an air classifier, and then deposited in trucks or stockpiled, depending on whether there is a customer for the scrap. Experience at New Castle has been that about 3 percent of the incoming waste is recovered as ferrous scrap. [2,3,4]

The landfill receives about 1200 tons of waste per day, six days per week, although the actual amount ranges from 800 tpd to 1400 tpd. About one-third of this is industrial waste or construction debris which is unsuitable for shredding and is delivered directly to the fill, bypassing the shredding plant. Additional quantities are bypassed when the feed conveyors are shut down to remove hazardous items, when mobile equipment is unavailable for loading waste or removing shredded material, and when the plant is down for repairs and maintenance. In general, the teed conveyors and shredders are operated no more than five hours out of each 10-hour processing day. Over the first six and one-half years of operation, the facility shredded an average of 40 to 45 percent of the waste delivered to the landfill. [2]

AENCO and the county have found that with normal compaction, one cubic yard of landfill space will hold about 850 pounds of non-shreddable material (including cover), 1100 pounds of unshredded material (including cover) of the type that is normally shreddable, or 1730 pounds if the latter material is shredded. Each ton that is shredded thus allows an additional 561 pounds of non-shreddable waste or 726 pounds of shreddable waste to be landfilled. [2]

FINANCIAL ANALYSIS

Because AENCO and the county jointly participate in the shredding and landfill operation, we shall examine the financial experience of each party. We shall look first at AENCO's operations and then at the county's.

Sources of Revenue: AENCO

AENCO receives most of its revenues from three sources -- the sale of recovered scrap metal, fees charged to the county for operation of the shredding facility, and payments by the county for major repairs and improvements to the facility.

Sales of Scrap Metal--

Extraction of ferrous metals began in November 1973, at which time a small amount of ferrous scrap (mainly tin cans) was sold to the M&T Chemical plant in Baltimore for detinning. This was not a viable market due to transport distance, and was succeeded a few months later by the Metals Cleaning & Processing Company, a Milwaukee company which built a detinning plant in Wilmington primarily to handle scrap coming from the AENCO facility. The price, f.o.b. the detinning plant, was based on the current price of a No. 1 scrap bundle; at 35 percent of the bundle price, this generally amounted to about $30 per ton. [4,N]

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Between 1974 and October 1977, at which time Metals Cleaning & Processing went bankrupt, $470,000 worth of scrap was sold for detinning. Under the agreement between AENCO and the county, AENCO received 25 percent of these revenues and the county received the remainder. Since the bankruptcy of the detinner, no new buyer has been found, although AENCO continues to separate and stockpile ferrous scrap. It is anticipated that stockpiled scrap can be sold for $30 per ton after delivery expenses. [N]

Processing Fees—
The county pays AENCO a fixed fee per ton processed to operate and maintain the shredding facility. At the time when the shredder became operational in January of 1973, AENCO was paid $3.25 per ton of waste shredded, a price comparable to the company's 1971 estimate of $3.00 per ton. At the end of the shakedown period, in March of 1973, the fee was reduced to $2.85 per ton, with the county agreeing to pick up the cost of electricity (then about $0.27 per ton). An escalation clause was also introduced which tied the fee to changes in the Consumer Price Index. In mid-1979, the fee was about $4.80 per ton. [2,N]

Contract Services—
Because the county owns the shredding plant, the county reimburses AENCO for major repairs and improvements which AENCO makes to the facility. Payments for these services are done on an individual contract basis between AENCO and the county in each instance. [N]

Statements of Income: AENCO

Using unpublished data provided by AENCO, Inc., we have constructed income statements for AENCO's portion of the shredding/landfill operation. In examining these figures, the reader should keep in mind that the results presented reflect a very specific set of operating and cost-sharing arrangements between AENCO and the county and are not necessarily indicative of the incremental costs of the shredding operation.

Conventional Analysis—
Annual revenues and expenditures for AENCO's portion of the shredding/landfill operation are provided in Table 20 for fiscal years 1976 to 1979. Operating revenues in the table include the components mentioned earlier. Operating expenditures include only the direct expenses of operation because the county owns the plant and AENCO has no capital expenditures directly related to the facility. AENCO does, however, conduct research and development activity at the facility, as shown by the line item under "Other expenditures" for 1976. These R&D activities are described further in a later section.

Of particular interest in Table 20 is the fact that AENCO has realized a small, but positive, profit in three of the four most recent years of operation. While profits have been modest, ranging from $0.01 to $0.38 cents per ton, they have apparently been sufficient to justify AENCO's interest in continued participation in the project. AENCO has no fixed capital tied up in the facility, except perhaps for the $300,000 in unreimbursed modifications

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TABLE 20. OPERATING DATA, NEW CASTLE COUNTY, DELAWARE, SHREDDING AND LANDFILL OPERATION (AENCO'S OPERATIONS)

(All dollar amounts in thousands of dollars, except per ton amounts)

	Fiscal year[1]			
	1976	1977	1978	1979
Operating revenues				
Processing fees	572	693	756	778
Other services[2]	202	189	50	44
Sales of scrap[3]	26	21	2	0
Miscellaneous	12	10	64	15
Total operating revenues	813	912	873	837
Operating expenditures	845	908	816	835
Operating profit (loss)	(32)	4	57	2
Net processing cost[4]	819	887	814	835
Other expenditures				
Research and development	100	0	0	0
Refuse shredded (10^3 tons)	126	147	151	139
Operating revenues per ton	6.45	6.20	5.78	6.02
Operating expenditures per ton	6.71	6.18	5.40	6.01
Operating profit (loss) per ton	(.25)	.03	.38	.01
Net processing cost per ton[4]	6.50	6.03	5.39	6.01

1. AENCO fiscal year runs from June 1 to May 30.

2. Payments to AENCO by the county for major repairs and modifications to the shredding plant, including repairs of explosion damage; the latter have generally been partially reimbursed by insurance.

3. AENCO's share of total scrap revenues.

4. The net cost of processing is taken to be total operating expenditures less revenues from the sale of recovered scrap or energy.

NOTE: Entries in table may not add to subtotals and totals due to independent rounding.

Source: A. R. Nollet, President, AENCO, Inc.

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(in 1972) mentioned earlier, and benefits from the association with the facility in terms of gaining operating experience and having a test-bed for experimentation and development.

Replacement Cost Analysis--

Because the county owns the shredding facility, the replacement cost analysis is carried out in the section dealing with the county's activities.

Sources of Revenue: New Castle County

The county derives revenues from three sources -- license fees charged to haulers, tipping fees charged to haulers, and revenues from the sale of scrap metal.

The county recognizes two classes of haulers: licensed haulers and unlicensed haulers. The former are charged an annual license fee of $100 plus an additional $5 per truck for each truck (after the first) in a hauler's fleet. Unlicensed haulers, which primarily dispose of industrial waste, do not pay a license fee, but are instead charged a higher tipping fee compared to licensed haulers. [M]

Tipping Fees--

Licensed haulers are charged a tipping fee of $8.40 per ton, and unlicensed haulers are charged $10.20 per ton. These are higher than the tipping fees charged originally. When the landfill was opened in 1972, the tipping fee for licensed haulers was $3.50 per ton. In July 1975 this was increased to $5.50 per ton, and in July 1977 it was raised to $7.00 per ton. The present fee has been in effect since July 1978. Tipping fees for unlicensed haulers have risen proportionally throughout this period, while the license fee has remained relatively unchanged. [M]

The county is able to raise its fees as costs increase because the county effectively has no competition -- acting under authority granted by the state, the county has closed all other landfills in its jurisdiction for public health and environmental reasons. [M]

Sales of Scrap--

As described in an earlier section, the county receives 75 percent of any revenues from the sale of scrap metal recovered and sold by AENCO. While this represented an appreciable source of income in earlier years (over 6 percent in 1976), revenues from this activity ceased after 1977 when the detinning company went bankrupt.

Statements of Income: New Castle County

Using data provided by the county, we have constructed income statements for the county's portion of the shredding/landfill operation. In examining these figures, the reader should keep in mind the earlier remark that the results presented reflect a very specific set of operating and cost-sharing arrangements between AENCO and the county and are not necessarily indicative of the costs of the overall operation. In particular, to obtain the financial results for the overall operation, one would need to combine the results for

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the two parties, taking care not to double count transfers from one to the other. However, because the county's payments to AENCO have been very close to AENCO's actual expenses, the income statement for the county is a close approximation to the financial results for the overall operation.

Conventional Analysis—

Annual revenues and expenditures for the county's portion of the shredding/landfill operation are provided in Table 21 for fiscal years 1976 to 1979. The county and AENCO use different fiscal years, so one should use caution when comparing figures in Tables 20 and 21.

Operating revenues in Table 21 include the components mentioned previously. Expenditures, however, require further discussion. First, the lease payment for the land is the annual lease payment which the county makes to the city of Wilmington for use of the landfill site. Second, the category "Other expenditures" includes all payments to AENCO for operation and maintenance of the shredder, including major repairs due to explosion damage, payments for electricity to run the shredder, and all other expenses for operation of the scales, all mobile equipment, and the landfill operation itself.

Third, the continuing growth in expenses for interest and depreciation, as shown in Table 21, reflects a sequence of capital improvements at the landfill site, including the original shredding plant. These improvements have been financed with funds obtained from bonds issued at various times since 1973.

Fourth, a line item for indirect costs begins to appear in the table in fiscal year 1978. To the best of our understanding, this is an expense similar in concept to a General and Administrative (G&A) expense and was apparently not applied to the shredding/landfill facility prior to 1978.

And fifth, some 6000 tons of ferrous scrap have been stockpiled which are estimated to be worth a total of $180,000 net of delivery cost. The county would receive 75 percent of the revenues from the sale of this scrap.

An overview of the financial results presented in Table 21 shows that the county was coming progressively closer to breakeven operation until the most recent year. The operating loss had fallen steadily, reaching $0.60 per ton in 1978. Coincidentally, if the indirect cost item had not yet been applied in that year, the operation would have shown a small profit. Expenses were up, however, in 1979 in nearly all categories and raised the operating loss to about $2.00 per ton. Further analysis shows that even in 1979, as well as in 1977 and 1978, the operating revenues have been sufficient to cover all variable costs and indirect costs and to make a contribution towards payment of interest and debt.

Of particular interest is the last line in Table 21, which indicates the net cost of disposal per ton. The net cost of disposal may be defined as total operating expenditures less any revenues from the sale of recovered materials or energy. As can be seen, the net cost of disposal has grown from

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TABLE 21. OPERATING DATA, NEW CASTLE COUNTY, DELAWARE, SHREDDING AND LANDFILL OPERATION (COUNTY'S OPERATIONS)

(All dollar amounts in thousands of dollars, except per ton amounts)

	Fiscal year[1]			
	1976	1977	1978	1979
Operating revenues				
Tipping fees	1449	1730	2575	2611
License fees	5	10	12	15
Insurance reimbursement[2]	100	75	50	50
Sales of scrap[3]	98	70	0	0
Total operating revenues	1653	1885	2637	2677
Operating expenditures				
Lease payments for land	101	101	101	101
Other expenditures[4]	1470	1533	1847	2163
Interest	189	237	348	368
Depreciation	263	263	284	368
Indirect costs	-	-	280	334
Total operating expenditures	2023	2133	2860	3335
Operating profit (loss)	(370)	(248)	(223)	(658)
Net disposal cost[5]	1925	2063	2860	3335
Other revenues				
Interest	-	-	-	55
Rentals	-	-	-	54
Refuse received (10^3 tons)[6]	311	329	368	340
Refuse shredded (10^3 tons)[6]	126	150	155	131
Operating revenue per ton	5.32	5.73	7.17	7.87
Operating cost per ton	6.50	6.48	7.77	9.81
Operating profit (loss) per ton	(1.18)	(.75)	(.60)	(1.94)
Net disposal cost per ton[5]	6.19	6.27	7.77	9.81

1. County fiscal year runs from July 1 to June 30. AENCO fiscal year runs from June 1 to May 30. Table based on county fiscal year.

2. Insurance reimbursement for major repair costs due to explosion damage.

3. County's share of total scrap revenues.

4. Includes payments to AENCO for the shredder operation, payments for electricity to run the shredder, and all other expenses for operation of scales, mobile equipment, and landfill.

5. The net cost of disposal is taken to be total operating expenditures less revenues from the sale of recovered materials or energy.

6. Tonnages are estimated; see Sources below.

NOTE: Entries in table may not add to subtotals and totals due to independent rounding.

Sources: Revenue and expenditure figures are from the New Castle County Department of Finance. Tonnages received and shredded are from reference [2] for various dates, and from A. R. Nollet, AENCO President, for AENCO fiscal years. All figures converted to county fiscal years by Mathtech staff.

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$6.19 per ton to $9.81 per ton during the years illustrated. Most of this increase can be attributed to higher operating expenses, although the loss of scrap metal revenues has accounted for about $0.32 cents per ton of this increase.

In other chapters of this report we have drawn comparisons between the net disposal cost at each facility and the price charged by competing disposal alternatives in the area. In the case of the New Castle County facility, this type of comparison is not possible because, with the county's closing of the other landfills, there are no competing alternatives. An official of the county has made the statement that the shredding/landfill operation "...is more expensive than the conventional sanitary landfill but far less costly than incineration." [3] In our judgment, this is undoubtedly a valid assessment. We estimate that the incremental cost to the county for the shredding operation in 1979 was over $1.1 million, including both operating and amortized capital costs.* However, with no other landfills operating nearby, we cannot verify the conclusion directly; nor are there sufficient data for evaluating, in dollar terms, the benefits of the shredding operation, which include extending the landfill life and lowering the operating costs of of the landfill, to determine whether these benefits outweigh the incremental costs.

Replacement Cost Analysis--

A somewhat different view of the situation is provided when the income statement is recast with the shredding and landfill facility shown at its replacement cost rather than in terms of its historical cost. An income statement using replacement cost would be indicative of the facility's financial position if it were constructed in the current year. Hence the replacement cost income statement is the one which other cities should look at if they are in the process of considering a resource recovery project. In general, if construction costs have escalated at a faster rate than other revenue and expense categories since the original construction period, then the financial picture will appear worse compared to the historical cost basis. If construction costs have escalated at a slower rate, then the financial picture will appear better than the historical cost income statement.

Our best estimate is that the replacement cost for the facility, including the shredder, the landfill (excluding land cost), and improvements made since 1973; i.e., the leachate control system, roads, etc., would be

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* This figure includes payments to AENCO totaling $822,000; payments for electricity to run the shredder of about $56,000, figured at 40 cents per ton shredded; and amortization of the capital cost of the shredder at about $192,000, which is the annual payment at 5 percent interest over 15 years which is equivalent to the original purchase price of $1,995,000. Incremental costs are actually somewhat higher than $1.1 million since this figure does not include the capital or operating cost for the scales and mobile equipment used at the shredding facility.

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about $10.2 million. This figure was obtained by escalating the original cost of $2.99 million in 1973 and the $4.0 million in later improvements to the current year 1979 using the Handy-Whitman index of utility construction costs. Assuming that this amount would be amortized over 15 years but that an interest rate of 7 percent would now be required, the annual capital cost would be $1,115,000. When this figure is used in the estimated income statement for 1979 in place of the interest and depreciation charges, a net loss of $1,036,000, or $3.05 per ton, is obtained. The corresponding net cost of disposal also increases to $3,713,000, or $10.92 per ton. These figures are larger than those shown in Table 21 because construction costs have risen more rapidly than the general price level, and because interest rates are higher. In effect, this means that if New Castle County were going to invest in resource recovery, it is better to have done so when it did rather than to have waited until 1979.

COMPARISON OF PLANNED VS. ACTUAL RESULTS

When the facility was originally built, both AENCO and the county had certain expectations about the financial and technical performance of the plant and about the opportunities for materials recovery. Since a comparison of these expectations with actual results will highlight some of the existing problem areas in the resource recovery field, we review the main differences below.

Shredding Fraction

The benefits of shredding, in terms of volume reduction and reduced cover and operating costs, will vary with the proportion of incoming waste which is shredded. Original expectations were that most of the incoming waste might be shredded by running the two 70-tph shredder lines for up to 12 hours per day, thus accommodating the expected peak deliveries of 1200 tpd. In actual experience, however, the plant has shredded an average of only 40 to 45 percent of the delivered waste. [2,3,N]

Several factors have combined to reduce the proportion of waste which is shredded. Foremost among these factors was the finding that between one-third and one-fifth of the incoming trucks contained material unacceptable to the shredders. These must be diverted directly to the landfill. Occasionally, however, unacceptable waste will pass through unnoticed in the midst of a load and cause jamming or breakage of the machinery, and in some instances, explosions. The cost of repairing explosion damage has been estimated to have added $0.60 per ton to the cumulative cost of the shredding operation (through 1978), and in one instance shut down one processing line for 18 months (1977). In an effort to cut down on losses from explosions, AENCO has designed and installed explosion vents and a micro-fog suppression system, and has installed barricades to protect personnel. Processing time is also lost when conveyors are stopped to allow inspectors to remove potentially damaging waste, or when mobile equipment is not available to load waste onto the conveyor equipment. [2,N]

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Materials and Energy Recovery

We have already mentioned the bankruptcy of the detinning plant and the subsequent loss of a market for ferrous scrap. Disappointments have also been encountered in attempts to market other materials recovered from the waste stream. These are reviewed briefly below.

Mushroom Compost—

In 1971 AENCO provided shredded solid waste, from operations at another location, to a mushroom grower for use as compost on an experimental basis. Both AENCO and the county expected revenue from this source once the county plant was in operation. A price of $10 per ton, f.o.b. the shredder, was the original expectation. These plans were ended in 1974, however, when the U.S. Food and Drug Administration ruled that solid waste products could not be used as mushroom compost. The FDA argued that mushrooms would absorb toxic materials from the compost and the FDA was also opposed to defining any "acceptable" contaminant levels, as an alternative to an absolute ban. [2,3,N]

Chicken Litter—

A more recent plan to use shredded waste as litter for chickens was also overruled by the FDA on essentially the same basis as the compost proposal. The FDA argued that the chickens would consume some amounts of the litter during feeding, and the FDA would have required a lengthy experimental program as well as a food additive petition and environmental impact statement. [N]

Refuse-Derived Fuel (RDF)—

In 1974 AENCO and the county explored the possibility of selling RDF to the local utility for test-burning. The utility was willing to pay about $5 per ton, f.o.b. the utility, a price at which AENCO believed the revenue would be sufficient to generate a small profit. The possibilities were not pursued, however, because it was feared that the State of Delaware would ultimately become involved in solid waste disposal, in competition with the county plant, and thus prevent full recapture of the necessary investment in processing equipment. [2,N]

The Rotary Drum Air Classifier (RDAC)

The problem of explosion danger and damage from other unacceptable wastes led AENCO to conclude that incoming waste should be air-classified prior to shredding rather than after shredding, as is more commonly done. The argument was that air-classification would allow removal of heavy materials, explosive and volatile material, glass (which accelerates wear of the shredder), and dust, which is a primary cause of explosions. For this purpose AENCO developed a patented device, the Rotary Drum Air Classifier (RDAC). The RDAC is a large rotating drum set at a slight incline and rotated while a stream of air is pulled up through the drum. This allows the lighter materials (the "light fraction") to be carried out the top while the heavier materials (the "heavy fraction") settle to the bottom. The light fraction is then more suitable for shredding since the potentially damaging materials will have been removed; the heavy fraction can also be screened to separate glass and sand.

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A full-scale prototype of the RDAC was successfully built and tested at the New Castle County site in early 1976. [2,N]

Unfortunately, no full production model of the RDAC was ever built. AENCO was unwilling to finance the construction without assurances of having a market for the light fraction to provide additional revenue, and the county, which must ultimately pay for maintenance to the shredder, was unwilling to finance construction without assurances that the device would be in use long enough to pay for itself. In September 1979 construction began on an entirely separate resource recovery plant in Wilmington funded by the Delaware Solid Waste Authority and the U.S. Environmental Protection Agency. The prospect of this plant coming on line in the near future has curtailed plans for additions to the county-owned site. Although AENCO proposed incorporation of the RDAC and the existing county shredding plant into the design of the new Wilmington plant, its proposal was rejected. However, a smaller version of the device has been in use at the county plant since 1975 for cleaning contaminants from the recovered ferrous scrap. [N]

CONCLUSIONS

In this section we attempt to answer three questions: First, is the New Castle County resource recovery operation economical? Second, if it is not, can this be attributed to the impediments catalogued in the Appendix? And third, what changes would be necessary to overcome these impediments? As in the earlier section on finances, we will consider the operations of AENCO and the county separately where appropriate.

Is the Facility Economical?

AENCO's Operations—

In the accounting sense of producing revenues in excess of costs, AENCO's portion of the shredding/landfill operation in New Castle County is economical. Modest net profits have been produced in each of the last three years, and the operation has in addition provided AENCO with extensive operating experience and with a test-bed for experimentation and development. It must be remembered, however, that these financial results reflect a very specific set of operating and cost sharing arrangements between AENCO and the county, the details of which have been described in earlier sections.

New Castle County's Operations—

When all cost elements are considered, the county's portion of the operation has not been economical, in an accounting sense. The county's portion of the shredding/landfill operation has generated revenues sufficient to pay all variable costs of operation, but only a portion of the expense for interest and debt retirement. However, the operating loss has been small — ranging from $0.60 to $1.94 per ton -- and the facility would have broken even in 1978 except for a change in the county's allocation of indirect costs.

It is more difficult to determine whether the county's operation can be termed economical in the broader sense of providing the least costly disposal alternative. In a qualified sense it is the least costly alternative because it is the only alternative -- our understanding is that the county, acting

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under state authority, has closed all other landfills in the county. A more relevant and far more difficult question, then, is whether the benefits of the joint shredding/landfill operation are sufficient to offset the increased costs compared to an ordinary sanitary landfill. We estimate that the incremental cost to the county for the shredding operation in 1979 was over $1.1 million, including both operating and amortized capital costs. However, there are insufficient data to evaluate, in dollar terms, the benefits of the shredding operation, which include extending the landfill life and lowering the operating costs at the landfill.

What Have Been the Impediments to Economical Operation?

Table 22 lists the various impediments to economical resource recovery catalogued in the Appendix, along with qualitative ratings of how each impediment has affected the experience in New Castle County. The following discussion summarizes the results presented in the table.

In our judgment, a number of factors have led to the county's financial situation with the shredding/landfill facility and also limited AENCO's profitability in the venture. Foremost among these factors were the limited experience with the design and operation of a shredding facility and the inadequacies of available technology which existed at the time the plant was first constructed. These factors led to a lower fraction of the waste being shredded than originally anticipated, with a consequent reduction in benefits from shredding, and also led to high costs for maintenance and repair. In particular, some of the problems which were not fully anticipated included: the large proportion of waste which must be diverted directly to the landfill without shredding; the design and operating practices necessary to reduce the frequency and damage from explosions; and the difficulty in coordinating the operation of the several conveyor systems, the shredders, and other processing equipment in order to maintain design output for extended periods of time.

Because the facility was designed as a materials-only recovery system, the financial performance of the facility has also been affected by less-than-anticipated revenues from recovered materials. The loss of revenues from ferrous scrap, and the difficulties in developing a market for compost, have kept AENCO's profits at a marginal level and contributed in part to the operating losses experienced by the county. The absence of a compost market can be traced directly to Food and Drug Administration restrictions on the use of compost, and on their unwillingness to consider establishing product standards for compost from solid waste. The problems with the ferrous market are more difficult to identify, but in any case are not helped by the preferential tax treatment and freight rates accorded to virgin materials which compete with scrap in the production of iron and steel.*

Finally, we should not overlook the role of the federal government and the State of Delaware in creating a climate of uncertainty with respect to

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* This issue is discussed in further detail in the Appendix.

TABLE 22. IMPEDIMENTS TO ECONOMICAL OPERATIONS (NEW CASTLE COUNTY, DELAWARE)

Impediment	No effect evident	Some effect probable	Large effect probable
Restrict quantity or composition of waste			
Pricing of landfills below full social cost	x		
Independent source-separation programs	x		
Returnables policy for bottles and cans	x		
Fragmentation of local government		x	
Restrictions on interstate movement of waste	x		
Seasonal or business cycle fluctuations	x		
Increase initial cost or restrict design			
Inadequacies of available technology		x	
High unit cost for equipment and parts	x		
Limited design experience		x	
Limitations on municipal financing	x		
Low first cost approach to public contracting	x		
Affect cost or efficiency of operations			
Limited operating experience		x	
Limited availability of spare parts	x		
Shortage of required labor skills including supervision	x		
State and federal regulation of air quality	x		
Restrictions on disposal of ash and residue	x		
Limit markets for available products			
Siting Restrictions	x		
Franchise restrictions on steam and electric sales	x		
Tax subsidies for virgin materials		x	
Price controls on oil and gas	x		
Lack of futures markets for scrap	x		
Unpriced mining and processing costs	x		
Differential freight rates		x	
Lack of product standards for reclaimed materials		x	
Rate regulation of electric utilities	x		
Restrictions on use of ash, residue and shredded materials		x	
Product labeling restrictions	x		
Government procurement policies	x		

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solid waste management in the New Castle County area. The $88 million facility which the state and federal government are now sponsoring in the Wilmington area may contribute to the state of the art in resource recovery activity. However, anticipation of the coming of this project, or at least the coming of a preemptive move by the state in the solid waste management area, are asserted to be the reasons behind unexploited investment opportunities by AENCO and the county. The uncertainty which this unresolved division of responsibility created is claimed to be the reason for the decisions not to build a production model of the RDAC at the county facility, and not to construct the equipment necessary to produce RDF for test-burning by a willing local utility.

What Changes Would Make the Facility Economical?

To illustrate the sensitivity of the income statements for both AENCO and the county to changes in various parameters, we carry out below some sample calculations. It should be stressed that the calculations represent order of magnitude estimates and do not take into account a variety of factors that would be considered in a more detailed study of the facility. The sensitivity analysis is conducted with respect to the financial results experienced in 1979.

Increased Shredding Fraction—

An increase in the fraction of received tonnage which is shredded will affect AENCO and the county in different ways. In AENCO's case, processing fees would increase and expenditures might remain relatively unchanged except for large increases in the shredding fraction. As an upper bound, each increase of 1000 tons shredded in 1979, with no increases in operating expenditures, would have increased AENCO's profits by $5,600. By the same token, if both processing fees and expenditures increase proportionally with tons shredded, then profits would actually decline by $410 per 1000 additional tons shredded. AENCO's profitability may thus be very sensitive to changes in the shredding fraction, depending upon how its costs vary with increased shredding.

On the county's side, changes in payments to AENCO, as a result of changes in the tonnage shredded, show up as a direct increase in expenditures. Offsetting this expenditure increase may be lower operating costs at the landfill since shredded waste requires less cover and other treatments. For the reasons mentioned earlier, the dollar value of these savings cannot be readily estimated.

Return of the Ferrous Scrap Market—

The plant typically removes 3 percent of the incoming waste as ferrous scrap. At $30 per recovered ton, this means that the scrap revenue potential in 1979 was about $300,000. The county's 75 percent share of this would have erased more than one-third of the county's operating deficit, and the 25 percent share going to AENCO would have represented a net profit of $75,000 for AENCO. A scrap price of about $86 per ton would have been required to erase the county's deficit entirely.

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2. __________, and R. H. Greely, "Two Million Tons of Solid Waste Processing Experience," paper presented to the American Public Works Association Congress, Boston, Massachusetts, October 1978.

3. William J. Connor (County Executive, New Castle County), "Shredding and Metal Salvage Give Landfill New Life," *The American City*, April 1973, pp. 77-79.

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ACKNOWLEDGMENTS

We are grateful to Mr. Anthony Nollet, president of AENCO, Inc., Mr. Albert Madora, Director of Public Works for New Castle County, and Mr. Michael Finnegan of the Department of Finance of New Castle County, who provided information and material in addition to the references cited above. Reference to information contributed by Mr. Nollet during our interview is denoted by the letter "N" appearing in the text. Reference to information contributed by Mr. Madora is denoted by the letter "M," and information provided by Mr. Finnegan is denoted by the letter "F".

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SECTION 8

AMES, IOWA

SUMMARY

The City of Ames, Iowa operates the first municipally-owned solid waste recovery system in the United States based on the production of refuse-derived fuel (RDF). Although the net cost of waste disposal has been much higher to date than was expected, the city's predictions for the future remain optimistic. If fuel costs continue to rise as they have in recent years and throughput continues to increase, then revenues from the sales of RDF and recovered material should be sufficient to cover all operating and capital costs by the mid-1980's.

BACKGROUND

Area Characteristics

Ames, the home of Iowa State University, is located in Story County in central Iowa. Story County has a total population of 65,000, of which 40,000 are in Ames. In addition to Iowa State University, Ames is also the home of U.S. National Animal Disease Laboratory, headquarters of the Iowa Department of Transportation, The Ames Laboratory of the U.S. Department of Energy, and other industry and agricultural-related business. The majority of the Story County area is fertile farmland.

Historical Methods for Solid Waste Disposal [6,C]

Prior to construction of the present resource recovery system in 1975, Ames had been operating a landfill. Initial consideration of resource recovery was prompted in 1970-71 by the state legislation which set strict regulations for landfill operation and required local governments to present comprehensive waste disposal plans by July 1975. In most of the state, responsibility for waste disposal was assumed by county governments, but Story County argued that since Ames contained two-thirds of the county's population and presumably two-thirds of the county's wastes, Ames should develop a waste disposal plan.

Cost of land disposal in 1971 was about $2.50 per ton, but an increased cost of at least 50 percent was anticipated if state requirements were to be met.

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Initial Planning for the Facility [C,3,6,10]

The landfill used by Ames and the surrounding area in 1972 was rapidly approaching capacity. A committee was formed to explore alternatives. The committee included members from the Ames Public Works office, the city manager's office, and Iowa State University. Three options were considered — sanitary landfill, shredding followed by sanitary landfill, and resource recovery. The first two options were ruled out because it was felt it would be very difficult, expensive, and wasteful to site a new sanitary landfill. Only two sites were found that satisfied the criteria established by the Iowa Department of Environmental Quality. To qualify, sites needed to be on high ground, which meant using some of the most fertile and expensive farmland in the midwest.

At the same time these events were taking place, the city's municipally-owned electric utility was becoming concerned about increasing prices and decreasing stability of fuel supply. For several years most of the utility's generating capacity had been supplied by natural gas, supplemented with high-sulfur Iowa coal. In the early 1970's natural gas prices began to increase at the same time that air quality legislation made the use of high-sulfur coal less desirable.

In October of 1972, Ames hired the consulting firm of Gibbs, Hill, Durham & Richardson (HDR) of Omaha, Nebraska to study the feasibility of recovering materials from the county's solid waste and burning the combustible fraction in the utility's power plant. The study, completed in the spring of 1973, concluded that the city could operate such a facility economically. It also concluded that the new system would be environmentally acceptable and would provide a new reliable source of low-sulfur boiler fuel while conserving the nation's natural resources.

In June 1973, Ames began the resource recovery project based on the HDR report, with the knowledge that two important markets were guaranteed. Twenty-five-year contracts were signed with every city and unincorporated area in the county as part of the solid waste disposal plan, which guaranteed sale of disposal service; and since the utility and recovery plant were jointly owned, the sale of refuse-derived fuel (RDF) was also guaranteed.

Initial estimates were that the resource recovery facility would cost $5.6 million to construct and $249,000 per year or $4.55 per ton to operate in 1975. Throughput was estimated at 54,750 tons per year. Cost of capital was estimated at $405,000 per year; fuel and metals credit were estimated at $6.90 and $2.10 to $4.45 per ton of solid waste processed, respectively. The net cost of disposal estimate was, therefore, $0.55 to $2.90 per ton in 1975, depending on the recovered metal market prices.

FINANCING AND CONSTRUCTION OF THE FACILITY [C,5,6,12]

The plant was financed at a final cost of $6.3 million through the issue of $5.3 million in general obligation bonds for 20 years at 5.32 percent and $1 million in federal revenue sharing funds. A special act of the state legislature was required to enable the city to borrow at a rate exceeding 5

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percent. Included in the financing was $1.6 million in modifications to the power plant to allow three coal-fired boilers to accept RDF.

Construction of the Ames resource recovery facility began in April 1974 and was completed in September 1975, about three months behind schedule. The first refuse was fed through the plant on August 30, 1975. Full-scale commercial operation began in January 1976.

OPERATION OF THE FACILITY [C,3,4,5,6]

Operation of the waste processing facility is under the direction of the Director of Public Works of the City of Ames. The plant is open for waste delivery Monday through Friday and Saturday morning, and waste processing takes place five days per week. The power plant that uses the RDF is operated by the Ames Electric Department. The Electric Department is also responsible for the operation of the RDF storage facility and conveyors for feeding the boilers.

All collection in the county is private, although cities may require licenses and insurance and allow franchises. There is no law that requires haulers to deliver to the plant, but they are encouraged to do so by virtue of a low fee -- $1 per truck. Government agencies and institutions who haul their own waste are charged a tipping fee based on weight. County residents may haul their own waste to the plant at a charge of $0.50 per car load.

Private haulers from outside the county are charged a tipping fee of $18 per ton.

System Description

The processing plant is located about 200 yards from the utility power plant and on the city's major east-west thoroughfare, U.S. 30, for easy user access. The plant accepts all residential and commercial solid wastes except demolition materials, automobiles, hazardous wastes, and dead animals. The process plant flow diagram is shown in Figure 4.

Entrance into the plant is divided to accommodate large trucks and small vehicles, such as cars and pickups. Weights of all regular trucks and vehicles using the scale are automatically recorded by the use of a punch card system.

The waste is deposited on a 16,000 square foot tipping floor. Initial hand-sorting of white goods, large aluminum pieces, and potentially hazardous items is carried out at this point. The waste is then pushed onto the infeed conveyor of the primary shredder by a front-end loader. The first stage shredder, which is a horizontal shaft hammermill with a 50-tph capacity and which is driven by a 1000-horsepower motor, reduces the material to a nominal 6-inch size. A three-stage electromagnet then removes approximately 90 percent of the ferrous metals. The ferrous metal is sent by conveyor to a semitrailer for transport and sale.

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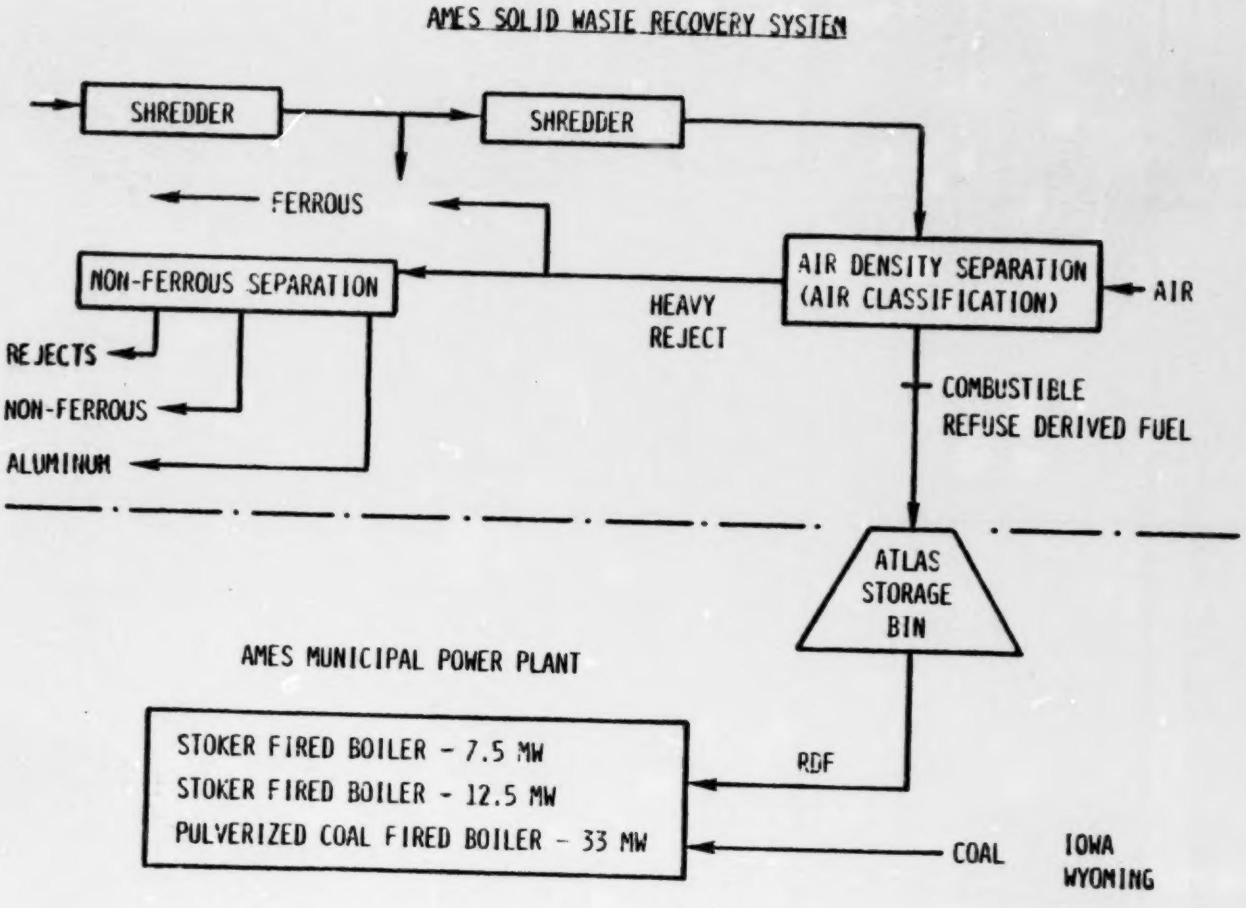
AMES SOLID WASTE RECOVERY SYSTEM
SHREDDER
SHREDDER
FERROUS
AIR DENSITY SEPARATION (AIR CLASSIFICATION)
AIR
NON-FERROUS SEPARATION
HEAVY REJECT
REJECTS
NON-FERROUS
ALUMINUM
COMBUSTIBLE REFUSE DERIVED FUEL
ATLAS STORAGE BIN
AMES MUNICIPAL POWER PLANT
STOKER FIRED BOILER - 7.5 MW
STOKER FIRED BOILER - 12.5 MW
PULVERIZED COAL FIRED BOILER - 33 MW
RDF
COAL
IOWA
WYOMING

Figure 4. Recovery system flow diagram.

Source: Reference [12].

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A second shredder, identical to the first but with smaller grate openings and lighter hammers, then reduces the material to less than 2 inches. This reduced material is sent to the air classifier. The air-classified light fraction (RDF) is pneumatically sent to the 500-ton capacity storage bin, from which it is pneumatically fed directly into the utility's coal-fired boilers. This RDF can be used as a fuel substitute on a 24-hour basis or intermittently as desired by the Ames Electric Department.

There are four separate pneumatic tubes leading to the power plant boilers. One tube leads to each of the two spreader-stoker boilers (8 and 12 Mw), and two lead to the suspension-fired boiler (33 Mw).

The heavy fraction of the waste stream from the air classifier passes through a second magnetic separator which removes most of the remaining ferrous metals. This ferrous metal is added to the ferrous metal recovered from the stream between the two shredders. The remaining material is conveyed by belt to a reject bin, from which it is periodically transported by truck to a landfill.

An aluminum separation system composed of a rotary trommel screen and an electrical eddy current separator was originally installed at the plant following the second magnetic separator, but this system, following a series of problems and modifications described later, is now inoperative.

A major modification was made to the Ames refuse separation system in late 1978. Two disc screens were inserted into the train immediately following the first magnetic separator before the second shredder. There were three major objectives in installing the disc screens. The first was to provide scalping of the shredded material so that particles 1.5 inches and under drop to the second screen and only the larger pieces are routed to the secondary shredder. This reduces power consumption and increases the wear life of the shredder. The second objective was to remove glass and grit before it became pulverized and embedded in the refuse fiber in the secondary shredder. The second disc screen, fed from the underflow of the first, removes particles under 3/8 inches. These fines are sent directly to the landfill. The portion from 3/8 inch to 1-1/2 inches is directed to the air classifier. Removal of the fines improves the quality of the RDF and reduces the wear on the pneumatic tubes and the floor of the storage bin.

The third objective of the disc screen was to improve the air classifier efficiency. With the fines under 3/8 removed, the air speed in the air classifier can be adjusted to remove a higher portion of the noncombustibles. This again results in a higher quality RDF. The RDF now represents about 75 percent of the incoming waste stream. Before installing the disc screens, it was 84 percent.

Materials Recovery

Ferrous metals (about 7 percent of the incoming waste) is the only recovered material bringing significant revenue to the city. White goods, wire, springs, etc., are hand-separated on the tipping floor and sold to a scrap dealer in Waterloo for about $6 to $10 per ton net (delivered to

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Waterloo). The remainder of the recovered ferrous metal is removed magnetically after shredding. The shredded scrap is sold via a five-year contract to Vulcan Metals, Gary, Indiana, for detinning. The price received f.o.b. Gary is 47.5 percent of the No. 1 dealer bundle price on the Chicago market, as reported in the third issue each month of Iron Age Magazine. Transportation to Gary is typically $20 per ton.

Vulcan Metals Co. is not entirely satisfied with the quality of scrap delivered, since contaminants run about 10 percent and they prefer less than 7 percent. The impurities are about 5 percent hang-on material and 5 percent lacquer, plastic, water, etc. The prices received for scrap has ranged between $35 and $49 per ton less transportation.

Smaller amounts of revenue are derived from a variety of sources. Hand-separated aluminum is sold to ALCOA. Mechanical separation of aluminum from mixed waste was originally planned, but this part of the process has been plagued with numerous problems and is inoperative. Problems incurred have included corrosion, excessive cooling water requirements, material pluggage, impurities in the aluminum product, damage to the magnets due to freezing of cooling water, and electrical problems resulting from fire damage. Work is continuing on a low-priority basis to resolve the problems with the system.

A wood chipper separate from the main processing line converts logs (0.9 percent of incoming waste) into wood chips which sell for $12.50 to $20.00 per ton for ground cover. Small quantities of wood are also sold as firewood.

Source-separated paper is baled and sold, and waste oil is stored in an underground tank and sold for $0.10 per gallon.

Energy Recovery

The recovered refuse-derived fuel (RDF) is fired as a supplemental fuel with Iowa-western coal mixtures in the Ames municipal power plant. Three boilers were modified to burn RDF. Two are stoker-fired and one is pulverized coal (PC) suspension-fired. The conceptual design of the waste recovery system specified burning RDF in the PC unit. Initial operation in 1975 resulted in a high dropout of unburned material into the bottom of the ash hopper. The power plant then began burning RDF in the stoker-fired boilers until a solution could be developed. The final solution was the installation of a dump grate in the bottom of the PC furnace, which was completed on April 26, 1978. The spreader-stoker furnaces are out of compliance since they do not have electrostatic precipitators.

Prior to the installation of the rotary disc screens in late 1978, RDF comprised about 84 percent of the waste stream, and had an energy content of around 5200 Btu/lb compared to 9030 Btu/lb for typical Iowa coal. Ash and moisture content are 18 and 25 percent, respectively, compared to 20 and 13 percent for Iowa coal. Since late 1978, the energy content of the waste is expected to have increased and the ash content decreased. Actual data are not yet available. [1]

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In practice the energy content of the RDF is determined indirectly since the RDF to the power plant is not weighed. The electricity produced from RDF and coal is compared to the electricity produced from coal having a known energy content. The quantity of RDF is calculated by difference since all the other outgoing products from the processing plant are weighed. Incoming wastes are weighed, except for private cars, where weight estimates are used. The total electricity consumption in the processing plant in 1977 was 66.9 kwh per ton of RDF. Using national averages for conversion to electricity, the processing energy requires about 334 Btu per pound of RDF. [9]

FINANCIAL ANALYSIS

Sources of Revenues

The Ames solid waste processing plant derives revenues from the following:

1. Disposal fees collected at the processing plant from private citizens, commercial firms, and contract refuse haulers.
2. Sale of materials separated from the waste stream, including metals, wood chips, and paper.
3. Revenue credit for refuse-derived fuel. This is a non-cash item since the refuse is delivered to the municipally-owned electric power generating plant. The value of the RDF is based on the dollar value of the coal that is replaced.

The operating cost in excess of the revenues above appears as an operating deficit and is allocated to the various communities in the county, according to population.

Disposal Fees

The cost of the disposal of waste is paid by all county residents directly or indirectly. Collection of residential and commercial waste is done by private haulers. Current collection fees are $2.50 monthly in most areas; $5.00 monthly in Ames (for twice-weekly collection). Some towns with franchise haulers charge $3.50 per month and apply $1.00 of the monthly fee to the deficit charge for disposal as described below.

Haulers from within the county are charged a tipping fee of $1.00 per truck at the plant. Government agencies and institutions which haul their own waste are charged a tipping fee based on weight (approximately $18/ton). County residents may haul their own waste to the plant at a charge of $0.50 per car. Private haulers delivering waste from outside the county are charged a tipping fee of $18 per ton.

Private customers deliver less than 10 percent of the total waste delivered to the plant, but they generate over 47 percent of the customer tipping fee revenue. In 1976 and 1977, tipping fees from all sources totaled $0.55 per ton of waste received.

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Revenue Credit for RDF

The price of RDF is based on the average cost of coal saved by burning RDF. The heating value of the RDF is somewhat higher than was projected. Original projections were based on experience in St. Louis where RDF had heating values in the 4500-4900 Btu/lb range. RDF heating value at Ames ranges between 5200 and 5700 Btu/lb. The higher energy content in Ames is attributed to the higher proportion of paper. Since the disc screen installation in late 1978, the energy content is somewhat higher, although accurate data are not yet available.

There is some consideration being given to adding a scale to monitor the quantity of RDF delivered to the power plant.

Statements of Income

A considerable number of analyses (including financial) of the Ames facility have been made by Iowa State University and Midwest Research Institute in a three-year study funded by EPA. These references and annual reports of the city were used to construct income statements for the facility for the years 1976 to 1978, with estimates for 1979. The analyses in subsequent pages represent our best judgment as to the plant's financial history. [2,14]

As noted previously, the plant was financed by a $5.3 million general obligation bond in addition to $1 million in federal revenue sharing funds. The bonds are paid at the rate of $200,000 per year plus interest for the first four years, and $300,000 per year plus interest thereafter. If the total amount had been financed, the annual reports would include principal and interest payments for the entire $6.3 million. To provide for greater comparability with resource recovery projects in other communities, and to reflect the opportunity cost of having used the revenue sharing funds for this purpose, we have added an implicit amorization expense to the expenditure accounts. An interest value of 5.32 percent was used. The amortization period is assumed to be 20 years. Similar expenses were added in subsequent years for major equipment additions that were purchased using grants or cash.

Conventional Analysis

Table 23 provides a summary of the operating results for the recovery facility for the years 1976 to 1978, and an estimate for 1979.

An overview of Table 23 reveals that the dominant source of income is a non-cash item; that is, the credit for RDF. Income from tipping fees represents about 5 percent or less of the revenue. Throughput has varied considerably due to operating problems, and has always been well below the anticipated 55,000 tons per year. The actual plant capacity, assuming eight-hour days, five days per week, is 100,000 tons per year.

In 1978 throughput was particularly low because of a seven-week downtime for major plant modifications. Revenues in the three years have been

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TABLE 23. OPERATING DATA, AMES, IOWA SOLID WASTE PROCESSING PLANT
(All dollar amounts in thousands of dollars except per ton amounts)

	1976	1977	1978	1979[1]
Operating revenues				
Tipping fees	24	25	28	38
Sale of scrap metals[2]	101	105	91	125
Sale of baled paper	2	8	2	3
Sale of wood chips	2	3	1	2
RDF credit	319	353	363	515
Total operating revenue	448	494	485	683
Operating expenditures				
Supplies and services	368	355	383	400
Wages, salaries and fringes	144	188	181	200
GO bond retirement	200	200	200	200
Interest on GO bonds 5.32%	282	271	261	250
Debt retirement and interest forgone[3]	82	98	107	142
Total operating expenditures	1,076	1,112	1,132	1,192
Operating profit (loss)	(628)	(618)	(647)	(509)
Net disposal cost[4]	652	643	675	547
Refuse processed (10^3 tons)	40.9	48.4	37.0	48.0
RDF produced (10^3 tons)	34.4	40.1	31.1	36.0
Ferrous metal recovered (10^3 tons)	2.9	3.0	24.4[2]	3.1
Non-ferrous metals recovered (10^3 tons)	0.005	0.009		
Wood chips (tons)	0.3	0.06		
Baled paper (tons)	-	0.08	0.02[5]	0.03
Operating revenue per input ton	10.95	10.21	13.11	14.23
Operating cost per input ton	26.31	22.98	30.59	24.83
Operating profit (loss) per input ton[6]	(15.35)	(12.77)	(17.49)	(10.60)
Net disposal cost per input ton	15.94	13.29	18.24	11.40

1. Figures for 1979 are projections by FAL staff.

2. Includes ferrous and small quantities of non-ferrous material.

3. Line item added by FAL to reflect opportunity cost of using revenue sharing funds; amortized in 20 years at 5.32 percent. Value increased annually because of purchase of additional capital equipment.

4. Net cost of disposal is the total expenditure less revenues from scrap and RDF.

5. Includes wood chips.

6. If a loss, then this item is assessed to the communities according to population. Note, however, that Item 3 above was added by FAL. Thus, the actual assessment is $2-3 per ton less.

Source: Ames Public Works Department and References [5] and [9].

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insufficient to cover even the variable operating costs. Revenues from tipping fees, of course, are extremely low compared to most solid waste operations.

Of particular interest is the bottom line of Table 23, which shows the per ton net cost of disposal. The net cost of disposal can be defined as total operating expenditures, less revenues from products. The per ton net cost of disposal can be viewed as the tipping fee required for breakeven operation. This value has ranged from $13.29 to $18.24 per ton of waste. If one looks at the first nine months of 1978 (since the plant was down for seven weeks in late 1978), then the per ton cost of disposal is $12.11 in 1978, and the breakeven tipping fee appears to be steadily decreasing on a year-to-year basis.

The operation's financial picture is made somewhat more attractive by two trends operating in its favor. First, fuel prices and thus RDF credits are likely to increase faster than the general rate of inflation and the rate of increase in other plant expenses. Thus, the current ratio of revenues to variable expenses is likely to grow. Second, the annual expense for debt repayment and interest should remain stable for the next several years. Thus the revenues could gradually catch up with the total operating expenditures. If one assumes, for example, that in 1980 and beyond RDF credits grow at 10 percent per year, interest and principal continue as described above, with no new major capital costs, and all other revenues and expenses grow at 6 percent per year, the recovery plant could show an accounting profit in 1988 or 1989. This analysis assumes a constant throughput and no revenue from aluminum recovery.

Replacement Cost Analysis

A somewhat different view of the situation is provided when the income statement is recast with the facility shown at its replacement cost rather than in terms of its historical cost. An income statement using replacement cost would be indicative of the recovery plant's financial position if the facility were constructed in the current year. Hence the replacement cost income statement is the one which other cities should look at if they are in the process of considering a resource recovery project. In general, if construction costs have escalated at a faster rate than other revenue and expense categories since the original construction period, then the financial picture will appear worse compared to the historical cost basis. If construction costs have escalated at a slower rate, then the financial picture will appear better than the historical cost income statement.

Our best estimate is that the replacement cost for the facility including the improvements made in 1975; i.e., the grates for the pulverized coal boiler, the paper baler, disc screens, dust collection system, and sprinkler system, would be about $10.9 million. This figure was obtained by escalating the basic facility cost of $6.3 million in 1975 and the 1976-1978 improvements to the current year 1979 using the Handy-Whitman index of utility construction costs. Assuming that this amount would again be amortized over 20 years but

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that an interest rate of 7 percent would now be required, the annual capital cost would be $1,029,000. When this figure is used in the estimated income statement for 1979, a net loss of $946,000, or $19.71 per ton, is obtained (see Table 24). The corresponding net cost of disposal also increases to $984,000, or $20.50 per ton. These figures are larger than those shown in Table 23 because construction costs have risen more rapidly than the general price level, and because interest rates are higher. In effect, this means that if Ames were going to invest in resource recovery, it is better to have done so when it did rather than to have waited until 1979.

TABLE 24. REPLACEMENT COST ANALYSIS FOR AMES, IOWA WASTE PROCESSING PLANT BASED ON 1979 PROJECTIONS
(All dollar amounts in thousands of dollars except per ton amounts)

Operating revenues	
Tipping fees	38
Revenue from products	645
Total operating revenue	683
Operating expenditures	
Variable costs	600
Debt retirement and interest	1,069*
Total operating expenditures	1,629
Operating profit (loss)	(946)
Net disposal cost	984
Refuse processed (10^3 tons)	48
Operating revenue per input ton	14.23
Operating cost per input ton	33.94
Operating profit (loss) per input ton	(19.71)
Net disposal cost per input ton	20.50

* Assumes capital investment of $10.9 million amortized over 20 years at 7 percent interest rate.

Source: Projections by Franklin Associates, Ltd. staff.

COMPARISON OF PLANNED VS. ACTUAL RESULTS [C,5,9,11]

Ames' experience with the resource recovery project has differed from its expectations in several aspects. These differences are summarized briefly below. We should stress that in making these comparisons our intention is

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simply to identify past problem areas so as to improve future decision making about resource recovery.

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Waste Availability

The facility has operated at well below design capacity. Although plant capacity is 50 tph, indicating a 400-tpd capacity with eight hours of operation daily, an average of slightly over 150 tpd have been processed to date. This is partly the result of overestimating the quantity of processible waste which would be delivered and partly the result of downtime for maintenance and modification of equipment.

Design of the plant was based on volumetric estimates of waste tonnage and projections from national averages. Both turned out too high. Original estimates for total quantity of waste generated in the county were that in 1975 there would be 60,000 people generating 6.7 lb/day, or 73,400 tpy, increasing to a population of 78,000 in 1985 generating 6.95 lb/day, or 99,600 tpy. It was also estimated that 25 percent of the total generated would be industrial or construction waste unsuitable for processing which would be sent directly to the landfill. Seasonal fluctuations were expected to be 20 percent above and below average at different times of the year.

Thus, throughput was estimated at 210 tpd in 1975, increasing to 287 tpd in 1985, based on a five-day collection and processing week.

The 50-tph plant capacity indicated that in 1985 this quantity could be processed in four to seven hours' daily processing time. Actual quantities processed were 40,935 in 1976, 48,400 in 1977, and 37,000 in 1978; this is about 70 percent of original estimates. In 1978, about 13,000 tons of waste bypassed the recovery plant for a total of 5000 tons from Story County. Expanding market area for disposal service has been considered, but towns in surrounding counties have also entered into other long-term arrangements as a result of the state solid waste laws and are not likely to be attracted by an agreement that would increase their current disposal costs.

Cost of the Facility

The consulting engineer had estimated in 1972 that the total project, including boiler modifications, would cost $5.6 million. The actual cost in 1975 was $6.3 million. A comparison of the planned and actual costs is shown in Table 25. Although the construction costs matched pre-construction estimates reasonably well, the startup and minor equipment costs of $487,000 were about five times the estimate.

Operating Problems

Most of the operating problems associated with the Ames plant have been related to the handling of a material that is extremely inhomogeneous. As with many new technologies, there has been a continual process of repair and modification since the operation began. The degree of success in the operation of the various components of the system range from nearly trouble-

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TABLE 25. COMPARISON OF PLANNED AND ACTUAL COSTS

Capital investment	Estimated	Actual
Processing plant	$3,898,000	$4,116,526
Pneumatic conveyors	150,000	164,388
Storage bins	687,000	551,292
Electric work	114,000	314,020
Boiler modification	179,000	178,988
Land	156,000	108,068
Engineering	275,000	376,896
Subtotal	5,459,000	5,810,178
Minor equipment and startup	100,000	486.405
Total investment	$5,559,000	$6,296,583

Source: Reference [9].

free to almost total failure. In spite of the operating problems experienced, daily records from June 1, 1976 through 1977 show that the plant operated 372 days out of a possible maximum (allowing for holidays) of 408 days. Thus some waste was processed in each of 91 percent of the available days. [5,9]

Some of the major problems at the processing plant have included the following: [5,6,9]

1. shredder bearing failure
2. fires in the shredders, conveyors, and bins
3. conveyor jamming
4. too much oversized material for optimum air classifier operation
5. metal fatigue in the air classifier
6. vibrating feeder screen pluggage
7. drag chain breakage
8. cyclone separator pluggage
9. occasional plugging of ferrous recovery system
10. freezing water lines

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11. pneumatic conveyor wear and pluggage

12. RDF storage bin floor wear

13. aluminum separation -- multiple problems

14. excessive glass and grit in RDF causing boiler slagging

15. excessive dust in building

Some of these problems have been corrected by modifications (ranging from adding simple baffles to major additions costing over $400,000), or changes in operational procedures. Others, such as fires, are recurring problems which can be minimized only by careful monitoring and early detection. In 1977 there were 11 shredder fires and two storage bin fires. Downtime was less than two hours for each of the occurrences. Fires are usually caused by flammable material that is undetected or undetectable to the tipping floor inspector. On one occasion, five gallons of gasoline in small breakable containers entered the shredder.

Problems No. 3, 6, 7, 8, 9, 11, and 12 appear to be the result of using equipment that was designed for materials more uniform in size, shape, composition, and density than municipal waste. Some of the plugging problems have been virtually eliminated by specially designed modifications, removal of some materials, or more frequent cleaning. The vibrating conveyors appear to be undersized for 50 tph operation. Problem No. 5 was corrected by a reinforcement of the fatiguing metal plates. Plant design appears to have been responsible because the air classifier was coupled with a vibrating pan feeder which caused the metal fatigue.

The aluminum separation system represents a new technology. A number of problems have been encountered, ranging from material pluggage and water line freeze-up to inadequate separation. Several modifications have been made, including the installation of an air-knife to improve the separation efficiency. Modifications have been hampered by inaccurate schematic diagrams. As a result, the aluminum separation system is not operating. Efforts to put the system into operation are continuing on a low-priority basis. Since the recent adoption of the deposit law in Iowa, it is thought the aluminum content of the waste stream may be so low that aluminum reclamation will never be practical.

In late 1978, the plant was down for about seven weeks to install two disc screens for additional removal of glass and grit and to install a dust collection and sprinkler system. The Ames system consists of a single line, so any one of many components failing can prevent the entire plant from operating.

Revenues from Products

Income from RDF and metals in 1976 averaged $10.95 per ton of waste processed. This was about 80 percent of the pre-construction estimate of

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$12.20 to $14.81. Shown in Table 26 are the actual vs. estimated revenues per ton of refuse processed. Because of the inability to make the aluminum magnet work, there was no income from aluminum as had been projected. Recovery of the aluminum (about 0.3 percent of the waste stream) at $300 per ton would have added $0.90 per ton of waste.

TABLE 26. ACTUAL VS. ESTIMATED REVENUES PER TON OF REFUSE PROCESSED

	Estimated		Actual	
	1975	1976	1977	1978
Fuel value of RDF	9.07	$7.80	$7.29	$9.91
Recovered metals	$3.13 - 5.74	2.47	2.17	2.46
Tons of refuse processed	54,740	40,900	48,400	37,000

Source: Reference [5] and Table 23 of this section.

As shown in Table 26, the revenue from products is not only lower per ton than expected, but the total quantity of waste processed is considerably below the quantity expected.

Cost of Operations

The Ames solid waste recovery system has experienced operating and maintenance costs that are considerably higher than had been anticipated. Shown in Table 27 are the actual vs. estimated O&M costs for the Ames facility. It should be kept in mind that 1978 was not a typical year since there was a seven-week downtime during which there was no throughput, and yet the expenses were not significantly reduced.

TABLE 27. ACTUAL VS. ESTIMATED O&M COSTS PER TON OF REFUSE PROCESSED

	Estimated		Actual	
	1975	1976	1977	1978
Operating and maintenance costs	$ 4.55	$12.52	$11.22	$15.34
Tons of refuse processed	54,740	40,900	48,400	37,000

Source: Reference [10] and Table 23 of this section.

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CONCLUSIONS

In this section we attempt to answer three questions: First, is the Ames resource recovery operation economical? Second, if it is not, can this be attributed to the impediments catalogued in the Appendix? And third, what changes would be necessary to overcome these impediments?

Is the Facility Economical?

In the accounting sense of producing revenues in excess of costs, the Ames resource recovery facility is not at present economical. The facility's revenues have not been sufficient to cover even the variable costs. The remaining variable costs and the interest and principal payments (which for Ames are not really fixed costs) are paid for through assessments to each town in the county (and the county itself for unincorporated areas) according to population.

Nor is the facility economical in the broader sense of providing the least costly disposal alternative. The net cost of disposal at the resource recovery plant, including tipping fees and assessed operating deficit, has been significantly higher than the rate charged by landfill in neighboring counties (currently $8/ton).

There is some prospect that breakeven operation will be reached in the latter 1980's. If oil prices continue to rise as they have, the facility's revenue from the power plant may outpace operating costs. In addition, new revenue sources may eventually be developed.

What Have Been the Impediments to Economical Operation?

Table 28 lists the various impediments to economical resource recovery catalogued in the Appendix, along with qualitative ratings of how each impediment has affected the experience at Ames. The following discussion summarizes the results presented in the table.

In our judgment, much of Ames' financial difficulty with the resource recovery facility can be traced to having overestimated the quantity of waste that would be generated within the city, which led to building a facility whose economical operation required a larger throughput than was forthcoming, and to the mechanical problems of handling and processing solid waste. As a result of the mechanical problems, throughput was further reduced, and revenue from the sale of metals is lower than expected.

RDF credit is not as high as predicted since fuel costs at the power plant have not risen as rapidly as expected during planning and construction. The city has been told it could not use natural gas after 1975. However, more natural gas was burned in 1976 than in any preceding year. All gas usage stopped in 1977.

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TABLE 28. IMPEDIMENTS TO ECONOMICAL OPERATIONS (AMES, IOWA)

Impediment	No effect evident	Some effect probable	Large effect probable
Restrict quantity or composition of waste			
Pricing of landfills below full social cost		x	
Independent source-separation programs	x		
Returnables policy for bottles and cans		x	
Fragmentation of local government	x		
Restrictions on interstatement movement of waste	x		
Seasonal or business cycle fluctuations	x		
Increase initial cost or restrict design			
Inadequacies of available technology			x
High unit cost for equipment and parts			x
Limited design experience			x
Limitations on municipal financing	x		
Low first cost approach to public contracting	x		
Affect cost or efficiency of operations			
Limited operating experience	x		
Limited availability of spare parts	x		
Shortage of required labor skills including supervision	x		
State and federal regulation of air quality	x		
Restrictions on disposal of ash and residue		x	
Limit markets for available products			
Siting restrictions	x		
Franchise restrictions on steam and electric sales	x		
Tax subsidies for virgin materials		x	
Price controls on oil and gas	x		
Lack of futures markets for scrap	x		
Unpriced mining and processing costs	x		
Differential freight rates		x	
Lack of product standards for reclaimed materials	x		
Rate regulation of electric utilities	x		
Restrictions on use of ash, residue and shredded materials		x	
Product labeling restrictions	x		
Government procurement policies	x		

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What Changes Would Make the Facility Economical?

To illustrate the sensitivity of the Ames facility income statement to various parameters, we carry out below some sample calculations. It should be stressed that the calculations represent order of magnitude estimates and do not take into account a variety of factors that would be considered in a more detailed study of the facility. The sensitivity analysis is conducted with respect to the financial results projected for 1979.

Increases in Throughput—

The first question of interest is the level of throughput required for breakeven operation. We can obtain an upper-bound estimate by making the assumption that all revenues and expenses, except interest and principal, are proportional to throughput. This allows one to develop the following algebraic expression for the incinerator's net profit:

$$\Pi = \frac{683}{48} \cdot Q - \frac{600}{48} \cdot Q - 592$$

where Q is the refuse processed. Solving for the breakeven value of A yields a throughput of 342,000 tons, or nearly seven times higher than the projected 1979 level, and over three times the maximum capacity of the plant. Thus no realistic breakeven level exists for the prices and costs prevailing in 1979.

To see what the throughput needs to be for breakeven operation at a tipping fee comparable to fees at landfills in neighboring counties, $8 per ton, the equation above becomes:

$$\Pi = 8.Q + \frac{645}{48} Q - \frac{600}{48} Q - 592$$

The throughput necessary is 66,200 tons per year, or 265 tpd, about 40 percent higher than the projected 1979 level. This is an upper-bound estimate because the facility is likely to have declining average per ton costs for throughput above 48,000 tons. A lower-bound estimate can be constructed by assuming that costs are unchanged for small increases in throughput above 48,000 tons. This leads to the profit equation

$$\Pi = 8Q + \frac{683}{48} \cdot - 600 - 592$$

and a breakeven throughput of 54,000 tons (216 tpd), or 13 percent higher than the projected 1979 level. The actual breakeven level (that is, assuming tipping fees of $8/ton) is thus likely to be somewhere between 54,000 and 66,000 tons (215-265 tpd). This does not appear totally unrealistic, considering the plant's maximum capacity is 400 tpd on a 250-day-per-year basis.

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Increase in Coal Prices--

An increase in RDF revenues of $509,000 would erase the projected deficit for 1979. To achieve this increase without increasing the quantity of RDF delivered would require an increase in the price of RDF and thus in the price of coal. If we assume that the projected 1979 RDF revenues are based on coal at $1 per million Btu, then the required increase in the price of coal turns out to be $0.99 per million Btu, or a 99 percent increase.

Increase in Metals Prices--

An increase in metals revenues of $509,000 would also erase the projected deficit for 1979. It is unlikely that such an increase could occur. To achieve such an increase would require a 500 percent increase in price, or in a combination of price and quantity recovered.

Combinations of Changes--

We have not explicitly considered above the possibility that several factors could be changed simultaneously. It seems clear, however, that if the throughput, coal prices, and metals prices all increased, for example, then the required increase in each case would be smaller than calculated above. It seems quite likely, in view of recent fuel price increases and recent modifications which should improve plant reliability, that this is the scenario that will take place.

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SECTION 9

MILWAUKEE, WISCONSIN

SUMMARY

Milwaukee, Wisconsin, is the largest U.S. city to have its municipal solid waste processed at a resource recovery facility. The facility is owned and operated by the Americology Division of American Can Company, and sells refuse-derived fuel (RDF) to the Wisconsin Electric Power Company. Thus the operation involves a cooperative effort between a large city, a large private corporation, and a public utility. High initial costs and operating problems with a complex recovery system have made the facility expensive and unprofitable in its early years of operation, but the plant's performance has improved steadily, and rising energy costs may lead to profitable operations in the next two or three years.

BACKGROUND

Area Characteristics [A]

Milwaukee is located on the western shore of Lake Michigan about 80 miles north of Chicago. The largest city in Wisconsin, it had a 1975 population of 660,000, out of about one million in Milwaukee County. The city's population has declined in recent years, although the population of the county has remained stable. The recovery system receives all municipally collected waste in Milwaukee as well as in several suburbs, including the county's second-largest city, West Allis (1975 population 69,000). Altogether, the system serves a population of about 800,000.

The employment base for both the city and the county is about 35 percent manufacturing, 21 percent wholesale and retail trade, and 13 percent government. American Can has operated manufacturing plants in the area for a number of years, and has been pleased with the work force available in Wisconsin and the competence and efficiency of local government in Milwaukee.

Historical Methods for Solid Waste Disposal [1]

Prior to 1970 Milwaukee disposed of solid waste both in landfills and by incineration. Air quality regulations adopted that year presented the city with the prospect of having to spend $20 million to control incineration emissions. Instead, incineration activity was ended so that by 1972 waste disposal was accomplished entirely through a system of city-owned, privately-operated landfills and transfer stations. The rising cost of landfill disposal at that time stimulated initial interest in resource recovery, but citizen interest in recycling and environmental issues, exemplified by the establishment of recycling centers, also contributed substantially.

Initial Planning for the Facility [1]

At the end of 1972 the city extended its landfill contracts for two years, and at the same time initiated a solid waste management study to investigate the possibility of undertaking resource recovery operations after that. In 1973 the city issued a fairly general RFP which attracted seven proposal submissions. In view of the city's association with the brewing industry, it is perhaps not surprising that those proposals incorporating production of RDF and materials recovery were rated highest, since materials recovery reduces the net social cost of disposable beverage packaging. American Can's Americology division was selected as the winning offeror ahead of such competitors as Waste Management, Inc. (WMI), which had been operating the city's landfill since 1970.

In January 1975 a 17-year contract was signed between Milwaukee and Americology, allowing two years for plant construction and providing for 15 years of plant operation, during which time the city promised to deliver at least 250,000 tons of waste to the plant annually at an agreed tipping fee, and Americology agreed to accept up to 400,000 tons annually. The agreement stipulates that Americology will own and operate the plant, although the city retains the option to buy the plant at an independently-assessed fair market price when the tipping fee comes up for renegotiation at five-year intervals after operation commences.

Americology simultaneously signed a 15-year contract with the Wisconsin Electric Power Company (WEPCO) whereby the utility agreed to purchase RDF for co-firing with pulverized coal in two of its base load boilers located in Oak Creek, 20 miles south of Milwaukee. Another agreement signed between Americology and WMI provided for the latter to continue operating the transfer stations and backup landfills.

FINANCING AND CONSTRUCTION OF THE FACILITY [1,A]

Ground breaking at the plant's nine-acre site on the Menominee River near the city's central business district took place in August 1975, and the plant began receiving waste in January 1977. Following a six-month startup period, the plant entered more or less continuous operation, gradually increasing the quantity of waste processed.

The initial capital cost for the system was estimated in 1975 to be $14 million for the recovery plant plus $4 million for RDF storage facilities and boiler modifications required by WEPCO. Financing arrangements were one of the last issues to be resolved during the planning stage, since some city departments wanted public financing. The city council regarded the project as

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risky and did not want to chance losing Milwaukee's AA bond rating. In the end, plant ownership (and risk) were given to Americology. In return, the city agreed to pay Americology a surcharge, in addition to a basic tipping fee, to cover the added cost of private financing and local property taxes.

Actual costs were $18.2 million for the recovery plant and $4.2 million for the WEPCO receiving and storage facilities, which the utility subsequently purchased. In addition, WEPCO spent $0.8 million on boiler face conversion. WEPCO now receives a discount on RDF purchases to cover amortization of both expenses. The recovery plant itself was financed in part by a $15 million revenue bond issue, backed by the American Can Company, with the remainder presumably financed by American Can alone. The revenue bond carried a 3 percent lower interest rate than conventional financing, and was arranged to provide American Can with ownership of the recovery facility.

Two further capital expenditure projects have occurred since the plant was built. In 1978, $1.7 million was spent on the RDF processing equipment to lower the glass content of the RDF from 8 percent to 5.5 percent, thus improving its quality. This equipment went on line in June 1978. Equipment to further reduce RDF glass content to 3 percent will come on line in January 1980 and will cost $4.0 million. These two improvements were privately financed by American Can.

OPERATION OF THE FACILITY

Waste Collection [4]

Milwaukee's waste is municipally collected by a fleet of 160 trucks and delivered either to the recovery plant or to one of three transfer stations operated by WMI. These stations also receive waste delivered from suburban towns participating in the operation. WMI operates a fleet of 42 trailers used for transferring waste and residue between transfer stations, the plant, and the landfill. These 75-cubic-yard trailers, holding 16 tons of waste each, are also used to ship RDF and recovered materials. Since storage capacity on the plant's tipping floor is limited to about two days' waste, the transfer stations also serve as storage facilities during extended downtime.

Plant Description [1]

A process flow diagram for the Americology plant is provided in Figure 5. Trailers and collection trucks from central collection districts deliver refuse to the plant's fully enclosed tipping floor where a wheeled loader pushes it onto conveyor belts after white goods and other bulky metal items are removed. The loading operation controls the process flow rate and allows inspection for potentially dangerous material. Two conveyors feed separate processing lines rated at 50 tph each with a surge capacity of 70 tph. The two lines operate independently, so the plant can continue to operate when one line is down. From the tipping floor, the conveyors pass a handpicking station where bundled newspaper is removed. Waste from each line is then shredded to six- to ten-inch particle size by a 1000-hp Williams horizontal

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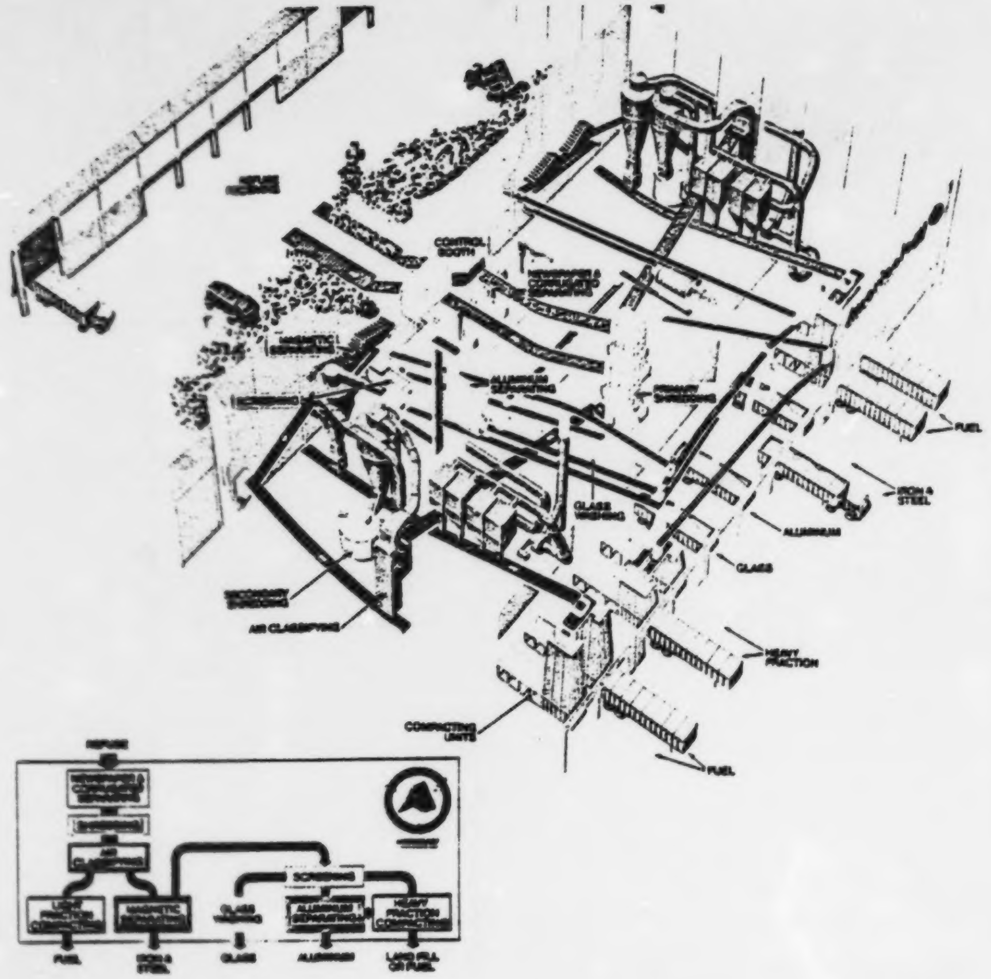
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LIGHT FRACTION COMPACTING
MAGNETIC SEPARATING
SCREENING
GLASS WASHING
ALUMINUM SEPARATING
HEAVY FRACTION COMPACTING
FUEL
IRON & STEEL
GLASS
ALUMINUM
LAND FILL OR FUEL

Figure 5. Process flow diagram for Americology.

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hammermill shredder and air classified in a zigzag classifier designed by Americology. The light fraction undergoes secondary shredding to 3/4-inch particle size and a belt magnet removes ferrous metal. The heavy fraction from the air classifiers is also passed under belt magnets to remove ferrous metal. The remainder of the heavy fraction is put through a series of trommels on one line and across a vibrating screen on the other line in order to remove glass which is washed for use as roadwork aggregate. The residue from the heavy fraction is sent to landfill, while refuse-derived fuel is sent to WEPCO's Oak Creek plant and stored in a 650-ton capacity Atlas hopper. In its original design, the Americology facility included equipment for extracting aluminum from the heavy fraction, but this equipment has not been in regular operation to date.

RDF Firing [A]

At the WEPCO Oak Creek power station, some 20 miles from the Americology plant, RDF is used to fire two base load boilers which are each rated at 310 MW, but normally run at 300 MW. At normal operation, they burn 125 tons of coal per hour, and are estimated to be capable of handling from 25 to 40 tph of RDF. Designed with close specifications to burn high-sulfur Illinois coal, they have a tendency to slag when RDF is burned, a problem which appears to have been made worse by the current firing of western coal. The RDF is rated at an average of 4900 Btu/lb, with a 29 percent moisture content and 30 percent ash content, compared to 15-25 percent moisture content and 10-20 percent ash content originally expected. The performance of RDF in the boilers has been upgraded somewhat by the improvements to reduce RDF glass content as described earlier. The rate of firing has increased from 10-15 tph two years ago to about 30 tph at the time of our visit. Moisture in the RDF has presented no problems. The heat recovered from RDF has been somewhat less than anticipated because some large particles do not burn out during the three seconds' firing time, a problem characteristic of the suspension boiler that would not occur with grate boilers.

OTHER RECOVERY OPERATIONS

As pointed out earlier, materials recovery reduces the net social cost of disposable beverage packaging. An alternative method of accomplishing this which is practiced in some areas is a mandatory deposit on beverage containers. The two are not complementary, however, since mandatory deposits can be expected to reduce the quantity of glass, ferrous metal, and aluminum in municipal solid waste. Americology officials have estimated that restrictions on the use of one-way containers would reduce Milwaukee's solid waste stream by 8 to 9 percent in weight and result in a loss of all revenue from aluminum recovery and 50 percent of the revenue from ferrous metal and glass. For this reason, the contract between Americology and the city specifically provides that in the event legislation should be passed which would reduce the amount of recoverable material in the waste stream, the parties would renegotiate for an additional charge to cover the revenue losses.

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FINANCIAL ANALYSIS

Sources of Revenue [1,A]

Americology receives revenue from three sources: tipping fees paid by Milwaukee and other cities for collected waste, the sale of RDF to WEPCO, and the sale of recovered materials to various buyers.

Tipping Fees—

In 1975, the initial tipping fee was set at $8.60 per ton (compared to $8.20 per ton for landfill disposal previously paid by the city), and has been adjusted annually in line with the Consumer Price Index. Thus in 1977 the tipping fee was $10.00 per ton (compared to a 1974 projection that landfill disposal would then cost the city $10.01 per ton), rose to $10.68 in 1978, and currently stands at $12.18 per ton. In addition, the city pays a tax compensation surcharge on each ton reportedly to compensate Americology for the added cost of private financing and local property taxes on the project. This charge was $2.00 per ton in 1977, was reduced to $1.50 per ton in 1978, and will increase in line with the CPI starting in 1979, when it rose to $1.67 per ton.

RDF Sales—

The sale price of RDF to WEPCO is based on the current monthly price of coal to WEPCO and the net cost of burning RDF. That is, Americology receives the same price per Btu for RDF as WEPCO would pay for the coal it replaces, but the amortized cost of the RDF receiving and storage facilities and boiler conversion are deducted; in addition, any added operating costs are deducted, and any operating savings (e.g., lower maintenance costs for coal pulverizers) are added. Examples of local coal prices in recent years are $0.91 per MBtu in 1977, $0.85 per MBtu in April 1978, $1.18 per MBtu in March 1979, and $1.27 per MBtu at the time of our visit to Americology in July 1979. The RDF produced has an estimated heat value of 4900 Btu/lb, or 9.8 MBtu/ton.

Sale of Recovered Material--

Americology has found markets for various materials recovered from municipal solid waste, including: bundled newspaper (1-2 percent of the waste processed at the plant), sold to the St. Regis Paper Company; and ferrous metal (6-8 percent), sold at present to Wisconsin Metals and previously to MRI detinners. The price of bundled paper was reported to be about $20 per ton in April 1978, although little or no bundled paper recovery has occurred since then. The price of ferrous metal is based on the price of a No. 1 scrap bundle, and was reported to be about $40 per ton in April 1978. No aluminum or glassy aggregate is being recovered and sold as yet.

Statements of Income [1,2,A]

Conventional Analysis--

Detailed financial results for Americology's operations are proprietary, so construction of income statements based on recorded actual revenues and expenditures has not been possible. Instead, we have constructed income statements for the years 1977 to 1979 based on prices and quantities which are

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publicly available and on other estimates provided by Americology personnel. For example, we were told by Americology personnel that the operation lost approximately $3 million in 1978 and is expected to lose approximately $2.8 million in 1979 before breaking even sometime around 1981 or 1982. An estimate of operating costs was derived on the basis of these figures, estimates of other expenditures, and estimates of operating revenues from prices cited above. The estimated income statements are provided in Table 29 and discussed further below.

From the plant's opening in January 1977 through the end of January 1979, 606,000 tons of waste were delivered to the plant or transfer stations for disposal, 206,000 tons were processed at the plant, 67,000 tons of RDF were sold to WEPCO (42,000 tons in 1978), and 11,000 tons of ferrous scrap were sold. Since the plant was closed in January 1979, all of these quantities appear in the table under the years 1977 and 1978 except 15,000 tons of delivered waste, our estimate for January 1979. There were several periods of extended downtime during these two years, however, and more recent performance for the period February through September 1979 may give a more accurate picture of the plant's present capability. During these eight months, 211,000 tons of waste were received for disposal, 116,000 tons were processed, and 53,000 tons of RDF were sold. Our estimates in the table for 1979, for refuse received and refuse processed, are an extrapolation of these figures to eleven months, plus the previously cited estimate of refuse received for January. The estimate of RDF sales in 1979 is based on the figure for eight months, plus a somewhat lower rate of sales in the final quarter of 1979 due to problems with boiler slagging at WEPCO.

Revenues from tipping fees are estimated using the quantity figures shown and average tipping fees of $10.00, $10.68, and $12.18, as cited previously. This is an underestimate since commercial haulers are charged a higher fee (currently $13.68). However, this may be offset by our estimate of the surcharge paid by the city, which is probably high. We have based the surcharge on total tonnage received, although the city may be liable for the surcharge only on waste originating within Milwaukee. Revenues from RDF are estimated based on the quantities shown, the average heating value of 4900 Btu/lb and prices of $0.91 per MBtu, $0.85 per MBtu, and $1.27 per MBtu respectively, as cited earlier. Revenues from ferrous metal and bundled paper are estimated based on the quantities shown and prices of $40 per ton, and $20 per ton, as cited previously.

The annualized capital cost for 1977 is estimated on the basis of $15 million financed at 7 percent and $3.2 million financed at a 10 percent after-tax cost of capital; a combined income tax rate of 50 percent, an investment tax credit of 10 percent, and a depreciation period of 15 years for tax purposes are also assumed. With a 15-year lifetime, this leads to an annual cost of $2,307,000 for the original plant investment of $18,200,000. This increases in 1978 because of the plant improvements costing $1,700,000, and again in 1979 for the current plant improvements costing $4 million. These latter improvements were financed privately and are shown in the table assuming an after-tax cost of capital of 10 percent; depreciation for tax purposes over 15 years and 8 years, respectively; investment tax credits of 10 percent and 20 percent, respectively; and lifetime of 15 years. The 1979

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TABLE 29. OPERATING DATA: AMERICOLOGY PLANT, MILWAUKEE, WISCONSIN
(All dollar amounts in thousands of dollars, except per ton amounts;
all physical quantities in thousands of tons)

	1977	1978	1979
Operating revenues			
Tipping fees	2,900	3,215	3,715
Sale of RDF (gross)	223	350	759
Sale of ferrous	160	280	360
Sale of paper	20	20	0
Surcharge from city	580	452	509
Total operating revenues	3,883	4,317	5,343
Operating expenditures			
Fuel rebate, city	22	35	76
Fuel rebate, WEPCO	775	775	775
Landfill disposal	2,080	2,008	2,115
Operating costs	1,206	1,327	1,510
Property taxes	600	600	600
Annualized capital cost	2,307	2,572	3,067
Total operating expenditures	6,990	7,317	8,143
Operating profit (loss)	(3,107)	(3,000)	(2,800)
Net disposal cost	6,565	6,632	6,948
Refuse received	290	301	305
Refuse processed	82	124	160
RDF sold	25	42	61
Ferrous sold	4	7	9
Paper sold	1	1	0
Waste landfilled	260	251	235
Operating revenue per ton received	13.39	14.34	17.52
Operating cost per ton received	24.10	24.31	26.70
Operating profit (loss) per ton received	(10.71)	(9.97)	(9.18)
Net disposal cost per ton	22.64	22.03	22.78
City's disposal cost per ton	11.93	12.06	13.60

Sources: Entries in the table have been estimated from data provided by Americology, or available in References [1] and [2], using procedures as described in the text.

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improvement should qualify for the higher tax credit and shorter depreciation period now allowed for resource recovery equipment, because it will be placed in service about January 1980.

Property taxes have been independently estimated at $600,000 annually. The fuel rebate to the city is equal to 10 percent of Americology revenues from the sale of RDF and is credited to the city against tipping fee charges. Landfill disposal of residue from the plant and unprocessed waste from transfer stations was estimated to cost $8.00 per ton in 1977-78 and $9.00 per ton in 1979. The quantity of waste sent to landfill is tons received, less RDF, ferrous metal and paper, sold. Finally, we have assumed that added operating costs and savings to WEPCO from firing RDF are either small or offsetting, so that the fuel rebate to WEPCO will be roughly equal to the amortization cost for the $5 million in improvements to the WEPCO plant. We have amortized this at the same rate as the original plant, which may be high if WEPCO has a lower borrowing cost. Note that this expense can be more than the value of the RDF sold to WEPCO.

Given Americology's estimate of the net operating losses for 1978 and 1979, an estimate of Americology's other operating costs in 1978 and 1979 were derived by adding total revenue and deducting other cost items. The net loss for 1977 was derived by assuming that other operating costs in 1978 had increased by 10 percent over the 1977 amount.

Of particular interest are the last two lines of this table, which highlight the net disposal cost per ton and the city's disposal cost per ton. Net disposal cost is total operating expenditure, less revenue from recovered energy and material, and less the fuel rebate to the city since the latter is merely a transfer. Note that this has remained relatively stable at $22-$23, since growing revenues, especially from RDF, have offset higher operating costs and the cost of the capital improvements in 1978 and 1979. RDF revenues are higher because both the proportion of total waste which is processed at the plant and the rate of RDF production have increased.

The city's disposal cost during this same period has risen from about $12 per ton to about $13. The city's disposal cost includes tipping fees and the surcharge paid to Americology, less rebates received from Americology's RDF sales. Note that the difference between the net disposal cost per ton and the city's cost per ton is Americology's loss per ton.

Several factors combine to provide an improved outlook for the facility. First, the price of coal, to which the price of RDF is related, will probably continue to increase at a faster rate than the general price level, to which most variable costs are probably related, so the real value of RDF should continue to rise. Second, when the new plant and equipment go into operation in 1980, the quality of RDF should improve and increased rates of material recovery, including some recovery of aluminum, are expected to develop. And third, periods of downtime appear to be decreasing, so the rate at which received waste is processed may continue to increase, thus cutting residue disposal costs and increasing revenue from recovered products. On the other hand, it appears that even if more RDF is available, WEPCO may not be willing to buy it for reasons which are discussed in a later section.

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Replacement Cost Analysis--

A somewhat different view of the Americology operation is provided when the income statement is recast with the facility shown at its replacement cost rather than in terms of its historical cost. An income statement using replacement cost would be indicative of the facility's financial position if it were constructed in the current year. Hence, the replacement cost income statement is the one which other cities should look at if they are in the process of considering an RDF/materials recovery project. In general, if construction costs have escalated at a faster rate than other revenue and expense categories since the original construction period, then the financial picture will appear worse compared to the historical cost basis. If construction costs have escalated at a slower rate, then the financial picture will appear better than the historical cost income statement.

Our best estimate is that the replacement cost for the facility would be about $28.4 million and that the replacement cost for the WEPCO storage facilities and boiler modifications would be about $6.2 million. These figures were obtained using the Handy-Whitman index of utility construction costs to escalate the initial cost of $18.2 million in 1976, and the cost of modifications of $1.7 million in 1978, to the current year 1979, and then adding the 1979 improvement costs of $4.0 million. Similarly, the $5.0 million cost of the WEPCO additions and modifications in 1976 were escalated to 1979 costs. Assuming that all plant and equipment would again be amortized over 15 years and with the same financing arrangements and costs, the annual cost would be $3.64 million for the Americology plant and $962,000 in annual rebates to WEPCO. When these figures are used in the estimated income statement for 1979, a net loss of $3.56 million is indicated, or $11.67 per ton received. The net disposal cost also increases to $7.71 million, or $25.27 per ton received. These figures are larger than those shown in Table 29 because construction costs have risen more rapidly than the general price level. In effect, this means that if Americology were going to invest in resource recovery, it is better to have done so when it did rather than to have waited until 1979.

COMPARISON OF PLANNED VS. ACTUAL RESULTS

Milwaukee's and Americology's experience with the resource recovery project have differed from their expectations in some respects. However, the burden of these problems has fallen largely on Americology since the city's financial exposure has been limited by the terms of their contract. The differences between expected and actual results are summarized briefly below. We should stress that in making these comparisons our intention is simply to identify past problem areas in order to improve future efforts at resource recovery.

Cost of the Facility [A]

Original estimates made in 1975 were that the total cost of the facility, including costs to WEPCO, would be about $18 million. As originally constructed, the total cost was $18.2 million for the Americology plant and $5.0 million for the WEPCO storage facility and boiler modifications. In addition, $5.7 million have been spent in the last two years. These latter

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modifications do not appear to be improvements in the design capacity or design performance of the operation, but rather an effort to bring the plant up to original design specifications. Thus capital expenditures have been about 60 percent higher than originally anticipated, which has added about $5.02 per ton of waste received to processing costs.

Reduced Throughput [A]

The plant was designed to process up to 400,000 tons of waste per year (1600 tpd, 5 days per week, based on two shifts per day). In its early years of operation, about 300,000 tons were received annually, but the tonnage processed was considerably lower than this. Between 1977 and 1978 an average of 100,000 tons were processed annually, and in 1979 it appears that about 160,000 tons will be processed. Part of this reduced processing rate is due to operating problems which have kept the throughput rate at an average of 45 tph compared to the design rate of 50 tph. However, the plant was reported to be processing about 60 tph as of November 1979. Most of the shortfall has resulted from extended periods of downtime. Following the initial shakedown period, during which problems are to be expected, the plant ran intermittently, processing some waste every day, although below design capacity. An explosion in December 1978 put the plant out of operation for repairs for six weeks. Figures given in Table 29 for 1979 include February, during which the plant was out of operation for repairs for two weeks, and May, during which the plant was out of operation for two weeks due to maintenance on the WEPCO boilers. However, the rate at which waste is processed has continued to improve during the past year, and as of November 1979, the plant was operating on one shift per day and was on line 65 to 75 percent of the time.

More recently, operations have been cut back to one shift per day, three days per week, with maintenance performed on alternate days. This was done because of reduced purchases of RDF by WEPCO projected for 1980. WEPCO has continued to experience boiler slagging with coal firing, a problem further aggravated by the RDF. In addition, a problem with one of the WEPCO turbines has been encountered for reasons unrelated to the use of RDF, and thus only one of the two boilers is currently operating.

Revenue From Recovered Materials [A]

Table 30 below presents recovery rates and prices for recovered materials anticipated in June 1975. Actual recovery rates (sales) have been somewhat lower than anticipated, and prices have been lower in some cases and higher in others. The rate of RDF recovery is presently about 46 percent (of tons processed), but is expected to go higher in the near future. Its price has been considerably higher due to rising fuel prices paid by WEPCO. Paper recovery has been lower than anticipated, and the actual price paid is not known. The low recovery rate is due to low participation rates among households, many of whom apparently withhold paper from the waste stream for donaton to paper drives. It is thought that paper recovery may increase as more residential suburbs are incorporated into the recovery system. No price incentives are offered to households to bundle paper, and advertising

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TABLE 30. PLANNED VS. ACTUAL RECOVERY RATES (SALES) AND REVENUES
(Annual tonnage based on 300,000 tons per year received waste)

Material	Tonnage[1]		Recovery Rate[2]		Price/ton[3]		Revenue[4]	
	Planned	Actual	Planned	Actual	Planned	Actual	Planned	Actual
RDF	180	61	.60	.20	$ 5	$ 13	$ 900	$ 759
Paper	15	0	.05	0	30	20	450	0
Ferrous metal	18	9	.06	.03	50	40	900	360
Aluminum	1.8	0	.006	.00	300	350	540	0
Glass	21	0	.07	0	5	2	105	0
Total	236	82	.79	.23	-	-	$2895	$1119
(Residue)	64	230	.21	.77		(9)	-	(2070)

1. Tonnages sold in thousands of tons. Actual figures projected on basis of eight months' operation.
2. Tons sold as a percentage of tons received.
3. RDF price as of June 1979; other prices are estimates based on Americology factsheet.
4. Revenue in thousands of dollars; discrepancies due to rounding.

Sources: Planned figures from correspondence from L. C. Bielicki, June 10, 1975; Actual figures from Americology factsheet, February 1979; telephone communication, November 1979; correspondence, February 1980; and Mathtech estimates.

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expenditures to encourage bundling are not known. Recovery rates for ferrous metal are lower than anticipated, and the price appears to be lower as well. Aluminum is not yet being recovered, although a higher price is now expected when aluminum recovery commences. The recovery of glassy aggregate on a commercial scale has been more difficult than expected and no sales of glass have yet been made.

Other Operating Problems [A]

Although RDF produced to date has been adequate in most respects, some problems have been encountered due to slagging in the WEPCO boilers. This is partly because the boilers were designed to very tight fuel specifications and have difficulty firing fuel other than high-grade coal, and partly because glass and grit contents of RDF were higher than anticipated. After initially experiencing RDF production with glass and other contaminants at around 8 percent, $1.7 million was spent to replace vibrating screen glass separators on one line with disc screen separators, which reduced glass content to between 5 and 6 percent. Modifications now being carried out on the air classifier are expected to reduce this to 3 percent. This should encourage WEPCO to use more RDF and help to eliminate another problem; the fact that when RDF is left for several days in the storage bin it tends to bridge and prevent uniform feeding to the boilers.

Part of the slagging problems appear to be the result of burning low-Btu high-ash western coal, however, and not strictly because of firing RDF. It is not clear whether this is done because Illinois coal, for which the boiler was designed, has not been economically competitive or because low-sulfur western coal is required to bring the boilers in line with air quality regulations. In either case, under current arrangements WEPCO has few economic incentives to buy more RDF because it simply pays the same price as for the coal replaced and because in any case the cost of RDF is passed on to users.

Although WEPCO has bought all RDF produced in the past, it does not appear that this will be the case in the near future. For reasons noted previously, sales of RDF to WEPCO in 1980 are projected to fall to 30,000 tons. If WEPCO should decline to purchase additional RDF, Americology would have to find another customer or else produce energy in a different form, such as steam, which would require further capital investment. No additional customers have been located as yet. Despite this potential problem, Americology feels that RDF production is appropriate for large cities, but future Americology plants may be designed for steam production using grate boilers, in locations where adequate markets can be guaranteed.

CONCLUSIONS

In this section we attempt to answer three questions: First, is the Americology resource recovery operation economical? Second, if it is not, can this be attributed to the impediments catalogued in the Appendix? And third, if so, what changes would be necessary to overcome these impediments?

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Is the Facility Economical?

In the accounting sense of producing revenues in excess of costs, the Americology recovery operation is not at present economical. The facility's revenues appear to have been about sufficient to cover variable costs of operating the facility and landfill disposal of residue and unprocessed waste, but only part of the required capital recovery. The remaining costs are paid by Americology.

Nor is the facility economical in the broader sense of providing the least costly disposal alternative. The net disposal cost at the facility has been about $22-$23 per ton, compared to an estimated $8-$12 per ton for landfill disposal in the area, including transport cost. It is true that to revert to landfill disposal might lead to a price increase at nearby landfills and would hasten the day when transport costs for residue and unprocessed waste would increase further due to longer hauling distances, but it may be some time before these costs rise to $23 per ton. The net cost of disposal to city residents, however, is much closer to what they might have to pay for alternative disposal arrangements. The current cost of about $13.60 per ton is near to earlier estimates of continued landfill disposal and is made possible because Americology absorbs the difference under current contractual arrangements.

As mentioned above, there is some prospect that the plant will break even in the mid-1980's. If coal prices continue to rise, the facility's revenue from RDF sales to WEPCO, and potentially to other customers, may outpace increased operating costs. In addition, new revenue sources are being developed from improved materials recovery techniques. Both of these revenue sources depend on continued demand for RDF and recovered materials, however. Speculation on whether these events will occur, and whether any future savings will offset current losses, is beyond the scope of this study.

What Have Been the Impediments to Economical Operation?

Table 31 lists the various impediments catalogued in the Appendix, along with qualitative descriptions of how each impediment is related to the experience at Milwaukee. The following discussion summarizes the results presented in the table.

In our judgment, much of Americology's difficulty with the Milwaukee resource recovery facility can be traced to having constructed a plant whose high initial cost means that throughput and the rate of recovery must be high as well for the operation to be economical. Failure to achieve high throughput and recovery efficiency seems to be due to mechanical problems of handling and processing solid waste. An additional reason for high fixed costs is that private financing was used because the city regarded the investment as too risky. Americology receives a tipping fee surcharge to compensate for this cost, but this still must be included in evaluating the net cost of disposal paid by Milwaukee residents.

Although WEPCO has purchased all of the plant's RDF until now, the utility appears to be balking at increased purchases because of problems with

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TABLE 31. IMPEDIMENTS TO ECONOMICAL OPERATIONS (MILWAUKEE, WISCONSIN)

Impediment	No effect evident	Some effect probable	Large effect probable
Restrict quantity or composition of waste			
Pricing of landfills below full social cost	x		
Independent source-separation program	x		
Returnables policy for bottles and cans	x		
Fragmentation of local government	x		
Restrictions on interstate movement of waste	x		
Seasonal or business cycle fluctuations		x	
Increase initial cost or restrict design			
Inadequacies of available technology			x
High unit cost for equipment and parts			x
Limited design experience		x	
Limitations on municipal financing		x	
Low first cost approach to public contracting	x		
Affect cost or efficiency of operations			
Limited operating experience	x		
Limited availability of spare parts	x		
Shortage of required labor skills including supervision	x		
State and federal regulation of air quality		x	
Restrictions on disposal of ash and residue	x		
Limit markets for available products			
Siting restrictions	x		
Franchise restrictions on steam and electric sales	x		
Tax subsidies for virgin materials		x	
Price controls on oil and gas	x		
Lack of futures markets for scrap	x		
Unpriced mining and processing costs	x		
Differential freight rates	x		
Lack of product standards for reclaimed materials	x		
Rate regulation of electric utilities		x	
Restrictions on use of ash, residue and shredded materials	x		
Product labeling restrictions	x		
Government procurement policies	x		

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slagging. It is possible that this can be traced indirectly to air quality regulations. The Oak Creek boilers were designed to burn high-sulfur Illinois coal, but have recently used increased quantities of low-sulfur, high-ash western coal. If this substitution was due to concern about SO_x emissions standards, then these standards have indirectly discouraged increased use of RDF. In addition, as we noted previously, WEPCO has little incentive to increase its purchases of RDF given the regulatory environment within which it operates (see the Appendix).

Finally, tax subsidies for virgin materials have probably had a small effect on the price for which recovered materials are sold, although no quantitative estimate of this is available.

What Changes Would Make the Facility Economical?

To illustrate the sensitivity of the income statement to various parameters, we carry out below some sample calculations. It should be stressed that the calculations represent order of magnitude estimates and do not take into account a variety of factors that would be considered in a more detailed study of the facility. The sensitivity analysis is conducted with respect to the projected financial results for 1979.

In general, profitability at the Americology plant will be determined by four types of variables -- quantity of waste delivered, percentage of delivered waste processed, recovery rates for RDF and various materials, and prices for RDF and recovered materials. A fifth variable, operating cost as a function of quantities processed and recovered, is unknown, but a rough estimate can be derived from the estimated 1979 figures. In 1979, we estimate that 160,000 tons of waste will have been processed with operating costs of $1,510,000. If operating costs are proportional to throughput, then a cost of $9.44 per ton processed is indicated. Since operating costs probably increase with, but at a rate less than proportional to, throughput, this is probably an upper-bound estimate for operating costs for throughput in excess of 160,000 tons. It also appears that quantity of received waste remains constant at about 300,000 tpy, so sensitivity to fluctuation in received waste will not be examined.

Increased Fraction of Waste Being Processed--

At present about 52 percent of received waste is processed, compared to an average of 35 percent in 1977-78. If recovery rates and prices for recovered products remain constant, then each additional ton processed adds $4.75 in RDF revenue, $2.25 in ferrous revenue, reduces landfill disposal costs by $3.94, and increases operating cost by up to $9.44. Therefore, if the 145,000 tons of waste received but not processed in 1979 had been processed, the deficit would have been reduced by an amount between $218,000 and $1,586,000. Even if the latter had been the case, this would not have been sufficient to eliminate the deficit.

Increased RDF Recovery Rate and Sales--

At present, the rate of RDF recovery (per ton processed) is about 38 percent, compared to 33 percent in 1977-78. If the percentage of waste

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processed and the price of RDF remain constant, then each additional ton of RDF recovered and sold adds $12.45 in revenue and reduces landfill disposal costs by $9.00. RDF recovery rate cannot be increased indefinitely without reducing its quality and eliminating revenue from other products, but a recovery and sales rate of 60 percent would have reduced the 1979 deficit by $755,000 if no additional operating costs were incurred by either Americology or WEPCO. This would not have been sufficient to eliminate the deficit.

Increased Rate of Ferrous Recovery and Sales—

The rate of ferrous recovery has been about 5.3 percent. If the percentage of waste processed and the price of recovered ferrous remain constant, then each additional ton of ferrous metal recovered adds $40.00 in revenue and reduces landfill disposal costs by $9.00. A recovery rate of 8 percent would have reduced the 1979 deficit by about $186,000.

Add Aluminum Recovery—

If aluminum recovery had been operating in 1979 at a recovery rate of 0.5 percent and scrap aluminum could be sold at a price of $500 per ton, then the deficit would have been reduced by about $400,000, assuming no additional operating costs were incurred.

Increased Coal Prices—

An increase in RDF revenues of $3.11 million would be required to erase the deficit for 1979, since the city receives 10 percent of these revenues. To achieve this increase without increasing the quantity of RDF delivered would require an increase in the price of RDF and thus in the price of coal. If we assume that estimated 1979 RDF revenues are based on a coal price of $1.27 per MBtu, then the required increase in the price of coal would be $5.20 per MBtu, or 409 percent.

Combination of Changes—

We have not explicitly considered the possibility that several factors could change simultaneously. However, if processing rate, RDF recovery and sales rate, and the price of coal all increased, then the required increase in each case would be smaller than those calculated above. In view of recent fuel price increases and improved plant performance, it seems likely that this is the scenario that will eventually take place, should WEPCO continue to buy all RDF produced.

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ACKNOWLEDGMENTS

We are grateful to Mr. George M. Mallan, Director of Operations and Technology Recovery Systems, American Can Company, and William L. Young, Manager of Marketing, Americology Division, American Can Company, who provided information and material in addition to the references cited above. Reference to information contributed by Messrs. Mallan and Young is denoted by the letter "A" appearing in the text.

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SECTION 10

MOUNTAIN VIEW, CALIFORNIA

SUMMARY

The Pacific Gas and Electric Company (PG&E), a large investor-owned utility serving northern and central California, owns and operates a methane recovery system at the Mountain View, California, landfill. Although the project was still in the demonstration phase at the time of our visit, it seems very likely that when it becomes operational in early 1980 it will be economically successful. Some questions remain unanswered concerning the technology of landfill gas recovery, but at locations where it is feasible it appears to be a promising method of resource recovery.

BACKGROUND

Area Characteristics [6,B]

The Mountain View, California landfill is located some 40 miles south of San Francisco at the base of the San Francisco peninsula. Although the landfill receives some municipal solid waste from Mountain View (1975 population 55,000) and three nearby cities, about 500,000 tons out of an annual total of 600,000 tons are hauled 33 miles from a transfer station to which all municipal solid waste from San Francisco (1975 population 665,000) is delivered.

The landfill is located in a 550-acre site which will eventually become part of the Shoreline Regional Park. Prior to 1966, this site was mainly flood plain containing a sewage treatment plant, dumps, a pig farm, and a car-wrecking yard. The 1966 park design called for developing 250 acres of sanitary landfill and 175 acres of earthfill (dikes, building pads, and roadways) in preparation for park use; the remaining 125 acres will become artificial lakes and wildlife refuge.

The Mountain View landfill site differs from other facilities we visited in two important respects. First, it is a regional disposal facility intended to take a relatively large amount of waste in a relatively short period of time (the total estimated capacity of solid waste of 4 million tons will be in place by 1985, two years after the current contract for delivery of waste from San Francisco expires). And second, the final land use of the site as a park determines its present use as a landfill rather than the other way around. Thus, unlike the typical case in which a city undertakes resource recovery to

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extend the life of a landfill or to postpone acquiring new land, landfilling at Mountain View is part of a park development and the motive for resource recovery is largely to improve the quality of the park. PG&E, likewise, is less interested in the disposal issues than in the opportunity for energy recovery.

PG&E Interest in Resource Recovery [3,4,B]

Pacific Gas and Electric's interest in resource recovery as an energy source dates from the early 1970's, at which time the company investigated various technologies then in use. A pyrolysis process* was identified as particularly promising in terms of producing a convenient and usable form of energy, but several drawbacks were also identified. High capital cost meant that a tipping fee of $15 to $20 per ton might be required; some technical loose ends such as waste water treatment were present; and it was felt that the involvement of parties with experience in waste disposal would have been necessary. Institutional difficulties were also encountered when PG&E started discussions to explore the possibility of building a pyrolysis plant. State authorities saw the project as a means of reducing the size of solid waste streams, and local authorities were interested primarily in finding low cost waste disposal. Securing agreement among the large number of local governments involved appeared overwhelmingly difficult, and this, coupled with the anticipation of high costs, led to the idea being dropped.

Nevertheless, PG&E remained convinced that substantial amounts of energy could be recovered from solid waste. Encouraged by the success of methane gas recovery projects in the Los Angeles area between 1971 and 1973, PG&E surveyed 32 existing landfills in the San Francisco Bay Area in the summer of 1974 and concluded that 14 of these had good potential for producing a combined total of 21 Mscfd (million standard cubic feet per day) of 450 Btu/scf gas. The Mountain View landfill was selected for initial study with federal EPA participation.

An important reason for selecting the Mountain View site, from EPA's point of view, seems to have been the fact that its average fill depth is about 40 feet, which is typical of landfills nationwide. Earlier gas recovery projects in southern California had utilized much deeper fills of about 150 feet; thus operating results from Mountain View would provide more widely applicable information about landfill gas recovery. The site was also attractive from PG&E's point of view because a 36-inch PG&E natural gas transmission line runs across the site, which meant that additional pipe would not have to be laid to transport gas.

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* Pyrolysis is a process in which organic materials are exposed to elevated temperatures in an atmosphere deficient in oxygen. The process can produce either oils or low Btu gases, depending on processing time and temperature.

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Initial Planning for the Facility [6,3,10]

Because the Mountain View facility has not yet taken its final form, the project is in some ways still in the planning stage. However, it will be instructive to examine planning which led to construction of the pilot project.

Although the process by which landfill gas is produced is known in some detail, the degree to which various parameters influence the process is not yet fully understood. Among other things, the rate at which gas is produced depends on the depth and configuration of the fill, the composition of the waste, soil permeability, moisture content of the fill, ambient temperature, and the rate at which gas is extracted. The Mountain View landfill was chosen because it is typical in many ways, but it was necessary to determine empirically the rate at which gas could be extracted while maintaining the biological process at equilibrium.

Between 1974 and 1976, tests were conducted to establish estimates of the rate at which methane is produced in the landfill and the rate at which the methane can be extracted. Results from two initial test wells indicated that wells at Mountain View have an effective radius of influence of 130 feet and produce 50 cubic feet per minute (cfm) of 450 Btu/scf gas. This is in comparison with pipeline natural gas which contains mostly methane and therefore has a heating value of about 1000 Btu/scf.

Based on the initial tests, further feasibility estimates were made and it was decided that a demonstration project to extract gas from about 30 acres of the landfill should be undertaken. The demonstration entailed drilling 18 additional wells, providing a total estimated gas production rate of about 1.116 Mscfd.

In order for the demonstration site to stay in production for at least ten years, the period used for evaluating the project, at least 24 percent of the carbon in the waste must be converted to methane, a reasonable expectation. Of course, the wells do not capture all the methane produced. Assuming an average fill density of 1000 lb/cy of waste, a landfill of 150 acres at a depth of 40 feet contains 4,842,000 tons. On the basis of test results, this much waste would produce 8.32 Mscfd of gas. Planning was carried out on the assumption that the Mountain View landfill could eventually produce 5 Mscfd, although the demonstration project was designed to produce about 1 Mscfd.

Uses of Landfill Gas Considered--

In general, there are four ways of utilizing landfill gas: upgrading and injection into a transmission line; upgrading and sale to an interruptible customer; on-site power generation; and on-site conversion to liquefied natural gas (LNG) or methanol. The experimental nature of the project made it impractical to attempt sale of gas to nearby industrial customers. On-site electrical generation or conversion to LNG or methanol were thought to require too much capital for a small-scale demonstration project. The proximity of the PG&E gas transmission line and the high capital cost of the other

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alternatives led to a decision to upgrade and inject the recovered gas into the transmission line.

Gas Clean-Up and Treatment Options Considered--

Treatment of landfill gas prior to transmission line injection may include dehydration, which produces a 500 Btu/scf product; dehydration and carbon dioxide removal, which produces a 700 Btu/scf product; and removal of all impurities including molecular oxygen and nitrogen, which produces a 975 Btu/scf product. In addition, these products may be mixed with propane to produce gas with the same heating value as pipeline gas (about 1000 Btu/scf). These treatments are progressively more costly, but result in a higher energy product and less moisture and fewer impurities that might otherwise cause corrosion.

Removal of all impurities was rejected as unnecessary since the quality of the pipeline gas would not be affected by the small quantity of landfill gas to be injected. With a 1 Mscfd plant running at design capacity, the dilution ratio is about 1:450 in winter and 1:300 in summer. Upgrading the heating quality to 700 Btu/scf was considered necessary in order to maintain regulatory specifications that gas sold to customers be within +2 Btu/scf of that shown on utility bills. The alternatives to this would be to adjust all appliances receiving mixed gas, or, if the change were sufficiently small, to obtain a variance from the regulatory agency. Two and one-half times as much propane is needed to bring gas without carbon dioxide removed up to pipeline quality compared to the amount needed for gas with carbon dioxide removed. For a 5 Mscfd operation, this would add more than the cost of carbon dioxide removal. In addition, simple dehydration without carbon dioxide removal was thought to reduce the heating value too much during periods of minimum flow in the transmission line, if gas were directly injected without adding propane, while this would not be true for small amounts of 700 Btu/scf gas produced by dehydration and carbon dioxide removal.

On the basis of the above considerations, it was decided to develop the Mountain View site using a process which would remove water and carbon dioxide from the gas and inject the gas directly into the transmission line without propane addition. A gas flow rate for the demonstration project of 1 Mscfd was selected because it was considered large enough to demonstrate economic viability of the concept while minimizing capital risk.

Initial Cost Estimates--

Estimated costs for a 5-Mscfd and 1-Mscfd operation are presented in Table 32. The total cost of the 1-Mscfd facility was estimated from received bids at $788,000 (early 1976). Cost estimates for the 5-Mscfd operation were based on vendor estimates obtained in mid-1975. Although propane addition is not done at Mountain View, information about this process is included to illustrate economies of scale which might be achieved with the larger plant size using alternative processes.

Annual fixed costs in Table 32 were calculated as .248 times initial cost. This fixed charge factor was set to include insurance (.001), *ad valorem* taxes (.030), income taxes (.057), and a capital recovery factor of .160 based on a 12 percent cost of capital, a ten-year project life, and a

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TABLE 32. PRELIMINARY COST ESTIMATES USED IN PLANNING FOR GAS RECOVERY AT MOUNTAIN VIEW, CA.

(All amounts in thousands of dollars except where noted)

	5 Mscfd[1] (mid-1975 $)	1 Mscfd[1] (early 1976 $)	Propane addition for 5 Mscfd[2]
Initial cost			
Equipment for gas treatment	405	245	46
Equipment for gas compression	370	200	135[3]
18 wells and collection system		70	
Installation	480	273	23
Total installed cost	1,255	788	204
Annual operating costs			
Fixed cost	311	195.5	50.5
Maintenance	44.5	24.9	2.7
Labor	30	30	0
Propane cost			1,514.5
Total annual cost	385.5	250.4	1,567.7
Thermal output (MBtu/yr)	620,000	97,650	1,084,000
Annual cost per MBtu ($)	0.62	2.56	1.45

1. Upgrading of 450 Btu/scf landfill gas to 700 Btu/scf using molecular sieves.

2. Upgrading of 700 Btu/scf treated gas to pipeline quality. Note that propane addition is not required for smaller plant size.

3. Propane storage cost.

Mscfd = million standard cubic feet per day.
MBtu = million Btu.

Source: Reference [3].

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salvage value of 30 percent. Annual maintenance cost in the table was estimated at 3 percent of process equipment cost plus 8.75 percent of compression equipment cost. Propane cost was based on a price of $.30/gal.

Note that total annual cost shown in Table 32 for the 5-Mscfd operation does not include the cost of installing a collection system, and that the cost of transporting processed gas to a more distant transmission line would have to be added in evaluation of other sites. Finally, the cost of royalty payments to the landfill owner for feedstock is not shown in the table, so these costs could reflect a situation in which the facility and landfill are owned by the same party.

Annual thermal output shown in Table 32 is based on the estimate shown for the overall thermal efficiency of the treatment process, and an on-line factor of 85 percent, or 310 days per year. The reliability of gas recovery and processing equipment is probably higher than reliability of equipment used in other resource recovery techniques because of the greater similarity between landfill gas and natural gas compared to the similarities between municipal solid waste and traditional solid fuels, so the on-line estimate of 85 percent is probably not overstated. The oldest methane recovery system at Palos Verdes is reported to have maintained an on-stream factor of 99 percent since it became fully operational following modifications in 1977. [11]

Financing and Construction of the Facility

Construction of the additional 18 wells began in August of 1977 and was completed in May of 1978, or about one month later than planned. Total construction cost amounted to $839,615, of which $270,000 was funded by a federal EPA grant to the city of Mountain View; the remaining cost was paid for by PG&E. Startup and operation commenced on June 2, 1978.

OPERATION OF THE FACILITY

Description of Disposal Operations [H,1,7]

The Mountain View landfill is a cut-and-cover operation in which refuse cells are excavated to a depth of 24 feet below existing ground level, with excavated material used to construct building pads, dikes, seals, and daily refuse cover. The water table in the area is about five feet below ground level, so extensive dewatering is required. Since the landfill will eventually be used as a park, marsh gas from the waste is a potential nuisance both because of its effect on vegetation and because it is a disamenity to park users. Pipes are placed in the bottom of cells for dewatering, and five-foot thick clay seals are placed along the sides and bottom to prevent water intrusion. These seals also inhibit lateral migration of gases. Refuse is compacted to a density measured at 1200 lb/cy and covered with six inches of daily cover. The final lift is covered with one foot of compacted clay and one foot of topsoil. The overall waste-to-cover ratio is four to one, so the average density of waste in the fill is 960 lb/cy.

When the landfill opened in 1970, it received about 50,000 tons of waste annually from the city of Mountain View (1970 population 54,000) and about

500,000 tons of waste annually from the city of San Francisco (1970 population 716,000), which represented all the municipal solid waste from these two cities. In 1974 the landfill began receiving an additional 75,000 tons annually from the nearby cities of Los Altos, Los Altos Hills, and Cupertino (combined 1975 population 56,000). Since 1970, the quantity of waste from Mountain View has remained roughly the same, and the quantity of waste from San Francisco has increased to about 550,000 tons. The landfill operators are currently under contract to continue taking waste from San Francisco through 1983, at which time the contract is expected to be extended for two years. After 1985, the landfill is anticipated to be near capacity; it is expected to be used only for waste from Mountain View from then until the year 2000. The portion of the landfill on which the PG&E wells are located was filled between 1972 and 1974.

Description of Gas Collection

The 20 wells at Mountain View are laid out in five rows of four wells each, with wells in successive rows staggered to form a triangular lattice with a constant spacing of 260 feet between well shafts. This is equivalent to saying that each well is at the center of a hexagon whose neighbors are centered 260 feet away. Raw landfill gas is extracted from the wells at the rate of 1 Mscfd and sent to the gas treatment plant on site. Only the 18 wells drilled in 1977-78 were considered to be in production (15 additional wells were also drilled in 1979 -- see below).

The spacing of the wells is based on the earlier finding that the test wells had a radius of influence of 130 feet. Each well thus utilizes the waste beneath the hexagon whose sides are 130 feet from the well. The quantity of waste which supports each well can be calculated on the assumption of waste at a constant depth of 40 feet and an average density of 1000 pounds per cubic yard. The area of a hexagon is $6r^2/\sqrt{3}$ where r is the distance from the center to the side of the hexagon. Thus the amount of waste utilized by each well is:

$$\frac{(6)(130\text{ ft})^2}{\sqrt{3}} \cdot \frac{40\text{ ft}}{27\text{ cf/cy}} \cdot \frac{1000\text{ lb/cy}}{2000\text{ lb/ton}}$$

The 20-well system is thus supported by 867,300 tons, and the waste for a 5-Mscfd operation is estimated at five times this latter amount.

In September 1979, 15 additional wells were drilled within the same area as the original 20. Thus a total of 33 wells are now in production on the 30-acre test site although the quantity of waste beneath them is the same as calculated previously for the original 20 wells. Current production from the system is 0.5 Mscfd with the raw gas having the following approximate composition:

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CH_4	48.00%
CO_2	34.10
N_2	12.00
O_2	0.90
H_2O	4.65
H_2	0.35
	100.00

Description of Gas Treatment [5]

A process flow diagram for the gas treatment plant is shown in Figure 6. Raw landfill gas at the rate of 1 Mscfd is extracted from 18 wells and compressed to 150 pounds per square inch, gauge (psig) in two stages. Interstage cooling with an air-cooled condenser produces water which is returned to the landfill at the rate of 0.1 to 0.3 gal/min. From the knockout pot, where water/gas separation takes place, saturated gas flows upward in a cylindrical adsorber where water vapor, carbon dioxide, and other impurities are adsorbed on an alumina gel desiccant, activated carbon, and molecular sieves. Treatment is done sequentially in three towers, with one tower on steam while the other two are being regenerated. Regeneration involves blow-down to atmospheric pressure followed by the application of a vacuum. During a portion of the blow-down cycle to atmospheric pressure, gas flows to the surge drum from which it is recycled to the suction of the compressor. From the adsorber, treated gas is compressed to 400 psig for injection into PG&E's line 101 serving the San Francisco peninsula. Control can be accomplished with a densitometer which monitors the specific gravity of the treated gas and adjusts the cycle time accordingly.

The crucial parameter in this process is the length of time required for the on-line adsorber to achieve saturation. If this occurs before the cycle time for which the equipment is set, because the adsorber was not fully regenerated, then carbon dioxide breaks through the adsorber and lowers the quality of treated gas. To compensate, the quantity of gas treated must be reduced.

OTHER RECOVERY ACTIVITIES

Materials Recovery [1,8,9]

Collection vehicles in San Francisco are equipped with bins for collecting newspaper and corrugated paper source-separated by households. This paper is recycled if the market price is sufficient to cover the cost of the operation. Although paper recycling has not occurred consistently since 1970, and appears not to be happening at present, source-separated paper was recycled for part of the period when the land where the PG&E wells are located was filled. Exact figures are not available for this period, but in 1975 an

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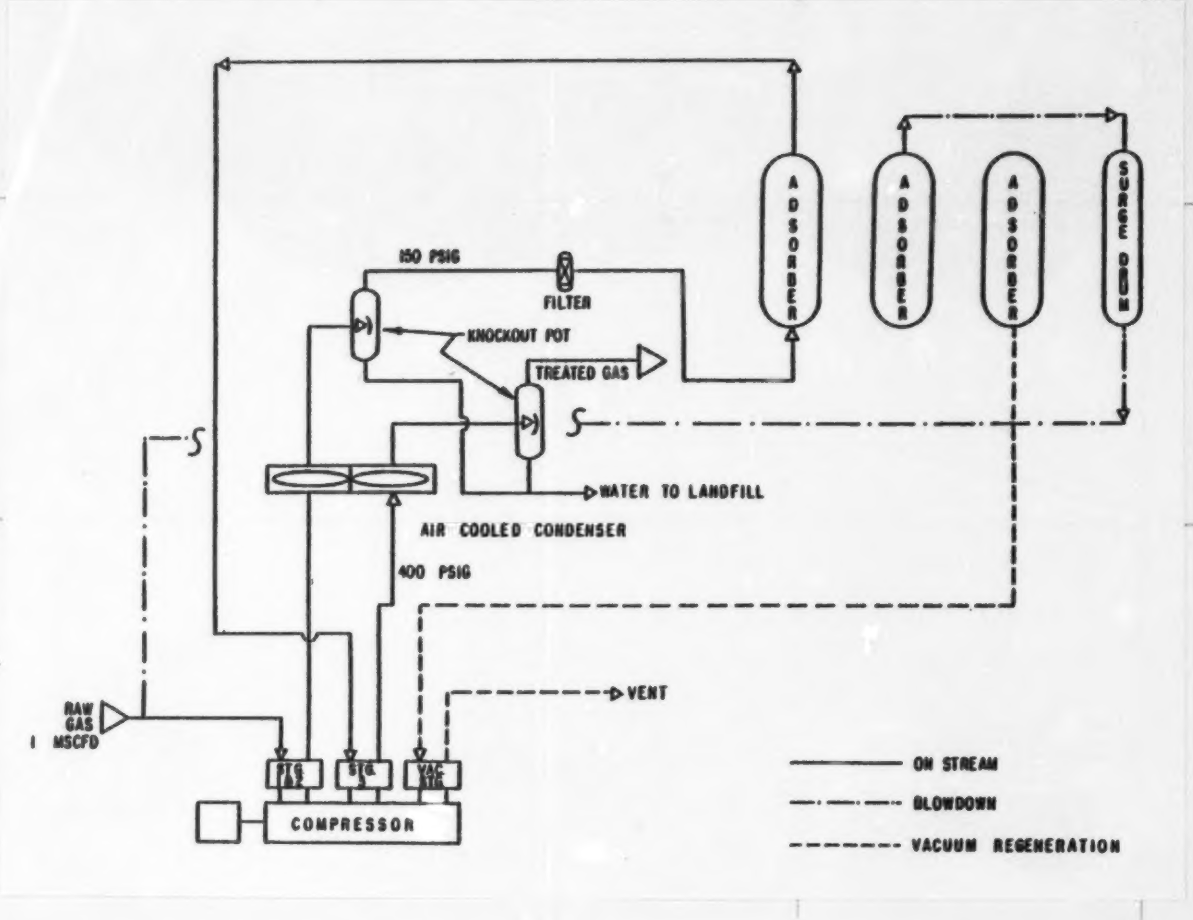
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400 PSIG
VENT
RAW GAS
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STG
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VACUUM REGENERATION

Figure 6. Operating schematic for Mountain View gas recovery plant.

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estimated 8300 tons of newsprint and 12,000 tons of corrugated paper were reportedly recycled, or about 4 percent of the waste stream destined for Mountain View.

The transfer station in San Francisco contains equipment to coarse-shred waste and remove ferrous metal with an electromagnet prior to shipment to Mountain View. Removal of ferrous metal is not currently practiced, but was earlier. Again, exact figures are not available, but in 1975 16,100 tons of ferrous metal, or about 3 percent of the waste stream destined for Mountain View, was reportedly recycled, primarily through activities at the transfer station.

Finally, there have been some small-scale source-separation recovery programs in operation in San Francisco since 1970, mainly involving glass and metal recovery. Ferrous metal recovered through these programs for 1975 is included in the figure cited above; glass recovery in that year was estimated at 500 tons.

Because the quantity of recovered methane does not depend on the quantity of waste delivered in the short run, the only effect of these activities on the Mountain View facility is to alter the composition of waste-producing gas. Extracting glass and metal from the waste stream tends to increase its organic content, while extracting paper has the opposite effect. Experience with methane recovery in Los Angeles has shown that different kinds of waste produce gas with slightly different composition, but these differences are mainly due to the presence or absence of industrial and chemical waste. Furthermore, extracting roughly equal amounts of organic and inorganic material is likely to have an offsetting effect. We shall therefore assume that the effect of material recovery at Mountain View has been negligible.

Materials recovery prior to landfilling may reduce the disposal cost paid by San Franciscans by providing revenues and reducing haul costs and tipping fee costs. It may also have some effect on cost of the landfill operation by slightly reducing throughput, but it appears that this throughput can be readily altered by not renewing contracts or by accepting waste from additional cities as was done in 1974. In any event, these changes in quantity of waste disposed will have no impact on the total cost or revenue from gas recovery, and will not be considered further.

FINANCIAL ANALYSIS

The Mountain View landfill and methane recovery project involves three separate parties. The city of Mountain View owns the landfill on which the gas recovery facility is located; PG&E owns the gas recovery and treatment plant; and a private firm operates the landfill. Under current arrangements, PG&E pays* the city a royalty on gas extracted from the landfill and can then

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* Payment of royalties began in January 1980 when the demonstration phase of the project ended and the production phase began. In July 1981 the royalty payments will be adjusted for inflation as provided by the contract between the city and PG&E described below.

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retain all revenues from the sale of recovered gas. The private landfill operator receives a fixed portion of landfill tipping fees to cover its operating costs and profit. The tipping fees are set by negotiated contracts between the city of Mountain View and other cities and municipalities.

Although there are three parties involved at the Mountain View landfill site, the landfill disposal and gas recovery processes are sufficiently separate, in both time and place, that we can concern ourselves primarily with the gas recovery aspects. The gas recovery project adds nothing to the cost of the landfill disposal operation at Mountain View, and in fact may actually reduce the cost for gas monitoring and control, although to an unknown extent. The project will ultimately pay royalties, however, and we will thus briefly consider the effect of these royalties on net disposal costs in our discussion of PG&E's gas recovery operations.

Sources of Revenue: PG&E

Gas which is processed through the treatment plant is injected directly into a PG&E transmission line which crosses the landfill a short distance from the plant. The appropriate transfer price for this gas, and thus the price one should use in calculating the revenues of the gas recovery project, is the long-run marginal price which PG&E must pay for gas from other sources. At present, PG&E obtains about 20 percent of its gas from California sources at $1.50 per MBtu, 40 percent from the Texas panhandle at over $2.00 per MBtu, and 40 percent from Canada at $3.45 per MBtu, f.o.b. the Canadian border. Liquefied and synthetic natural gas (LNG and SNG) are reported to cost between $4.00 and $5.00 per MBtu, f.o.b. the port of entry. Since the domestic gas sources are fully utilized, the long-run marginal price is somewhere between the Canadian price, plus transportation to the PG&E system, and the LNG/SNG price. We have therefore used $4.00 per MBtu as the transfer price for gas injected into the PG&E pipeline.

Sources of Revenue: Mountain View

In addition to royalty payments from PG&E, the City of Mountain View collects tipping fees from various cities delivering waste to the landfill. From 1970 to 1973 San Francisco was charged $2.20 per ton, of which $1.88 went to the landfill operator and $0.32 went to the City of Mountain View. In 1975 these payments were increased to $2.80 and $3.75 per ton, respectively. At present, Mountain View pays $0.62 per ton for disposal of its waste, a subsidized price. San Francisco pays a tipping fee of $5.44 per ton, of which $3.31 goes to the landfill operator and $2.13 to Mountain View for road maintenance, plus a surcharge of $2.00 per ton directly to Mountain View for other maintenance. The other cities pay a tipping fee of $6.55 per ton, of which $2.35 goes to the landfill operator and $4.20 for road maintenance. A weighted average tipping fee may be calculated by multiplying the tipping fee to each customer times the tonnage delivered and dividing by total tonnage. This weighted average is [(550,000 x ($5.44 + $2.00)) + (50,000 x $0.62) (75,000 x $6.55)]/[550,000 + 50,000 + 75,000] = $6.84 per ton at present.

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Statements of Income: PG&E

Using operating cost information supplied by PG&E, we have constructed an income statement for the recovery operation for the fiscal year 1979 and an estimate of what the income statement might look like once the recovery project enters the operational stage. We should stress two points about these income statements. First, the figures for 1979 reflect operating conditions for the project while it was still in the demonstration phase. During this period the plant logged only 1147 hours of operation, and thus gas recovery quantities and revenues are far below what one would expect once full-scale operation commences. To provide some indication of what normal operations might look like, we have also included estimates for operation at a 75 percent on-stream factor (6570 hours) stated in terms of 1979 dollars.

A second point to keep in mind is that the results presented reflect a very specific set of operating and revenue sharing arrangements between PG&E and the city of Mountain View. The costs and revenues for the PG&E facility thus may not necessarily be identical to the incremental costs and benefits of the gas recovery project, although one would expect them to be close. We will have more to say on this point later.

Conventional Analysis--

Revenues and expenditures for PG&E's portion of the landfill gas recovery project are shown in Table 33. As mentioned earlier, the table includes actual results for fiscal year 1979 and our estimate of the probable results for a full year of normal operation. Revenues from the gas recovery operation in both cases have been calculated using the transfer price of $4.00 per MBtu discussed earlier.

The estimated revenues for 1979 are based on raw gas with a measured energy content of 450 Btu per scf and an overall thermal efficiency for the treatment plant of 65.5 percent (a measurement made during 132 hours of continuous operation in May of 1979). Thus the facility produced (35 Mscf) x (450 Btu/scf) x (.655) = 10,300 MBtu of treated gas for injection into the pipeline. At a price of $4.00 per MBtu, this provides revenues of $41,200.

In estimating what the facility's performance and revenues will be when it becomes fully operational, three parameters are of particular interest: the rate at which gas is extracted, the amount of time the plant is on line, and the overall thermal efficiency. During a six-day period in May 1979, gas was extracted at a rate of 835 kscfd. Since that time additional wells have been drilled which may increase the overall extraction rate without impairing the viability of methane production, but this figure can be used as a lower bound. Also, over the period August through November 1979, on-line performance increased to about 50 percent compared to 13 percent during the previous year while in demonstration phase. An on-line performance of 75 percent, compared to the design goal of 85 percent, should thus be a conservative estimate of the plant's performance once it becomes fully operational. Finally, as mentioned previously, thermal efficiency has been determined to be 65.5 percent during continuous operation. Improvements may increase this to the 70 percent figure previously estimated. Therefore, a

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TABLE 33. OPERATING DATA, PG&E METHANE RECOVERY FACILITY, MOUNTAIN VIEW, CA.
(All dollar amounts in thousands of dollars,
except per ton and per MBtu amounts)

	Actuals for FY 1979* (1979 $)	Estimates for a full year (1979 $)
Operating revenues		
Sales of gas	41	270
Operating expenditures		
Labor	24	30
Materials	18	25
Indirect costs	26	26
Annualized capital cost	84	86
Royalty payments	0	21
Total operating expenditures	152	188
Operating profit (loss)	(111)	82
Gas extracted (Mscf)	35	229
Gas injected (Mscf)	14	92
Gas injected (MBtu)	10,300	67,500
Operating revenue per MBtu	4.00	4.00
Operating cost per MBtu	14.76	2.79
Operating profit (loss) per MBtu	(10.76)	1.21
Waste utilized (10^3 tons)	867	867
Ten-year revenue per ton	.47	3.11
Ten-year cost per ton	1.75	2.17
Ten-year profit (loss) per ton	(1.28)	.95
Ten-year royalty per ton	0	.24
Potential change in net disposal cost per ton	+1.04	-.96

* Based on figures for year ending June 30, 1979.

Sources: Non-capital expenses for 1979 are from unpublished PG&E data, as are the gas quantities extracted and injected. Other figures are Mathtech estimates, based on data supplied by PG&E, or calculated as described in the text.

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conservative estimate of gas extraction is (.75) x (365 days) x (835 kscfd) = 229 Mscf of raw gas providing (.655) x (229 Mscf) x (450 MBtu/scf) = 67,500 MBtu of treated gas. The revenue estimate is based on this quantity and the price of $4.00 per MBtu.

Expenses for labor, materials, and indirect costs in 1979 are actual amounts as provided by PG&E. No royalty payments were required during the period since these are not scheduled to begin until the demonstration phase has ended. The annualized capital cost is based on a total capital cost of $570,000 ($840,000 - $270,000 provided by the EPA grant), and a fixed charge rate of 14.77 percent. We have calculated the fixed charge rate assuming a cost of capital of 11.5 percent (PG&E's estimate at the time), an economic life of 20 years for the treatment plant with no salvage value,* a depreciation period of ten years (the middle of the range allowed for resource recovery plants), sum-of-years digits depreciation, a 10 percent investment tax credit, and 46 percent and 9 percent as the federal and state corporate income tax rates. Insurance and *ad valorem* taxes are not included in the fixed charge rate, unlike Table 32, because they have been included in the indirect cost expense mentioned above.

Expenses for a full year of operation are assumed to be only slightly higher than in 1979. Labor and materials are shown to be up only slightly with increased operation, based on the absence of any correlation we observed between monthly gas production and monthly expenses for labor and materials. Indirect costs will be about the same. Annualized capital costs are up slightly, reflecting the expenditure of $11,500 to drill the 15 additional wells in August of 1979.

Future royalty payments will be based on a three-part formula, as mentioned previously, the components of which include the Industrial Commodities portion of the Wholesale Price Index (now called the Producer Price Index), average hourly earnings in the California utilities industries, and the PG&E rate for residential gas sales. As an approximation to this formula, we have adjusted the base royalty of $.072 per kscf in November of 1976, to mid-1979, using simply the Producer Price Index for industrial commodities. The resulting royalty of $.0913 per kscf, multiplied by the quantity of gas extracted, yields royalty payments of $21,000.

The final set of figures at the bottom of Table 33 incorporates the calculation in an earlier section that approximately 867,000 tons of refuse underlie the 33-well system. Based on the yet-to-be-proven assumption that the field will produce a steady supply of gas for about ten years, one can estimate the per ton revenues, costs, profits and royalties that will accrue from this waste over the ten-year period. These items are shown at the bottom of the table. The estimates are stated in 1979 dollars and assume zero escalation, in real terms, during the period.

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* A given section of the landfill may produce gas for only ten years, but as additional sections are developed, gas production and thus the use of the treatment plant may extend over 20 years.

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Some caution should be exercised in interpreting the information in Table 33 due both to the fact that this is still a demonstration project and to uncertainties about the process of anaerobic methane generation. Actual operating figures are available for only one year, during which the project lost money, but this cannot be taken to mean that the project will be unprofitable once it is operational. Indeed, evidence to date indicates that the project will likely be profitable in the near future. Nonetheless, there remains a degree of uncertainty about the rate and extent of methane conversion, and variation in these factors would affect the figures in the table in a variety of ways.

Bearing these cautions in mind, we can develop an estimate of the change in net disposal cost per ton which could be brought about by methane recovery. This amount appears as the very last line in Table 33. The figure has been calculated by adding the per ton profit to the per ton royalty, and then converting this to present value terms using the assumption that profits and royalties are received in equal amounts at the end of each year for ten years. A real discount rate of 4 percent has been used since zero real escalation has been assumed. This quantity so calculated represents the amount by which the landfill tipping fees could be changed and still allow both the city and PG&E to break even. A positive quantity means that tipping fees would have to be increased; a negative quantity means that tipping fees could be decreased. The negative quantity projected for normal operation thus implies that methane recovery is likely to produce benefits which exceed costs, and thus lower the net cost of disposal. Given the assumptions stated earlier, the methane recovery project, when fully operational, could reduce net disposal costs per ton by nearly $1.00.

Replacement Cost Analysis--

A more complete view of the situation is provided when the income statement is recast with the facility shown at its replacement cost rather than in terms of its historical cost. An income statement using replacement cost would be indicative of the facility's financial position if it were constructed in the current year. Hence, the replacement cost income statement is what other cities should consider if they are in the process of looking into methane recovery. If construction costs have escalated at a faster rate than other revenue and expense categories since the original construction period, then the financial picture will appear worse compared to the historical cost basis, while if construction costs have escalated at a slower rate, then the financial picture will appear better than the historical cost income statement. The anaerobic digestion of waste occurs independently of when construction takes place. There is some evidence that steps can be taken in landfill design and operation to accelerate the process, and the extraction of methane affects the rate at which methane conversion takes place, but full control of this process is impossible.

Using the Handy-Whitman index of utility construction costs to escalate the cost of construction forward from 1977 to 1979, we estimate that the replacement cost for the 33-well facility would be $997,000. Assuming that the fixed charge rate will again be 14.77 percent, the corresponding annualized capital cost increases from $86,000 to $147,000, while all other revenues and costs remain the same. In the estimates for a full year of

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operation, this change would reduce operating profits from $82,000 to $21,000, and lower the potential reduction in net disposal cost per ton from $0.96 to $0.25. The capital cost is made so much larger both because of inflation and also because we have omitted the $270,000 EPA grant in order to obtain results which would be more widely applicable at other sites. Despite these changes, the facility would nonetheless appear to remain profitable, although at a lower level than before. In effect, this means that if PG&E were going to undertake landfill gas recovery at this particular site, it is better to have begun when it did rather than to have waited until 1979.

COMPARISON OF PLANNED VS. ACTUAL RESULTS

PG&E's experience with the landfill gas recovery project has brought some unanticipated problems. However, since the project has been largely exploratory to date, it makes less sense to speak of "expectations" as we have done in evaluating other cases. These problems are summarized briefly below. Our intention in pointing out these problems is simply to identify past problem areas in order to improve future efforts at methane recovery.

Cost of the Facility

The initial cost of the facility was originally estimated at $788,000 and in fact amounted to about $840,000. In addition, it was found that optimal gas recovery required the addition of 15 wells on the site at a cost of $11,500. These differences are relatively minor. No comparisons between estimated and actual costs for operation and maintenance are possible yet since the project is still in the demonstration phase.

Operating Problems [B,4]

Less than two weeks after the initial plant startup in June 1978, the bed support screens at the base of one molecular sieve tower failed, resulting in the vacuum cylinder and piston being scored. Following their replacement in August, it was determined that carbon dioxide breakthrough was occurring after six to eight minutes, compared to 20 minutes in the plant design. This was traced to water adsorption on the molecular sieve material, which was heated to drive off the water. In September 1979, the sieve material was replaced at a cost of about $18,500. Drying the original sieves increased cycle time to about 13 minutes, and the new material has increased cycle time further to about 17 minutes.

The other major operating problem concerns the introduction of oxygen from the atmosphere into the landfill. The full extent of this is not known, but it was found that after continuous operation of the facility for a week or two, nitrogen in the raw gas increased from 10 percent to around 25 percent. The 15 additional wells were drilled in the gas field in an attempt to spread the suction more evenly.

Finally, it has been suggested that because landfill gas, unlike natural gas, contains hydrogen sulfide which is corrosive and higher-order hydrocarbons which may be carcinogens (e.g., benzene and chlorinated

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hydrocarbons), it could be hazardous if it were not burned at high enough temperatures. Tests on processed gas have indicated that hydrogen sulfide is well within the design limits of four parts per million, and that trace amounts of higher-order contaminants appear to be within acceptable limits.

Two questions seem to remain unanswered at present: First, it has not yet been definitely proved that gas recovery can be accomplished at a shallow landfill such as Mountain View over long periods of continuous operation at extraction rates sufficient to make the process economical. This is not because of equipment inadequacies or process efficiencies, but because it is uncertain at what rate gas can be extracted from shallow depths without drawing in so much oxygen that anaerobic bacteria are destroyed. The addition of new wells should mitigate oxygen intrusion, and the answer to this question should be known in the near future. Second, there is uncertainty about how long landfilled waste will produce methane under various undisturbed conditions as well as with extraction taking place. This may not be known at Mountain View for some time, although research on the subject is being undertaken.

CONCLUSIONS

In this section we attempt to answer three questions: First, is the Mountain View landfill gas recovery facility economical? Second, if it is not, can this be attributed to the impediments catalogued in the Appendix? And third, what changes would be necessary to overcome these impediments?

Is the Facility Economical?

At the present time the Mountain View facility is in its demonstration phase of operation. For this reason, its operating hours have been limited and it has not been economical. However, most of the previously unknown factors influencing the facility's ultimate performance, such as thermal efficiency, rate of extraction, and rate of operation, give every indication that the facility will be economical even at levels of performance somewhat lower than originally planned. The most important outstanding uncertainty is how long and at what gas extraction rate the anaerobic organisms will remain viable.

What Have Been the Impediments to Economical Operation?

Table 34 lists the various impediments catalogued in the Appendix, along with qualitative descriptions of how each impediment is related to the experience at Mountain View. The following discussion summarizes the results presented in the table.

Evidently, no impediments to economical recovery have been sufficiently great to cause the project to fail, and in our judgment none of the impediments listed had a large effect. However, a few of these have probably caused the project to be less profitable than it might have been otherwise.

Landfill gas recovery is in its infancy, and many questions about this complex process remain unanswered. In some ways it is comparable to the level

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TABLE 34. IMPEDIMENTS TO ECONOMICAL OPERATIONS (MOUNTAIN VIEW, CALIFORNIA)

Impediment	No effect evident	Some effect probable	Large effect probable
Restrict quantity or composition of waste			
Pricing of landfills below full social cost	x		
Independent source-separation programs	x		
Returnables policy for bottles and cans	x		
Fragmentation of local government		x	
Restrictions on interstate movement of waste	x		
Seasonal or business cycle fluctuations	x		
Increase initial cost or restrict design			
Inadequacies of available technology		x	
High unit cost for equipment and parts	x		
Limited design experience		x	
Limitations on municipal financing	x		
Low first cost approach to public contracting	x		
Affect cost or efficiency of operations			
Limited operating experience		x	
Limited availability of spare parts	x		
Shortage of required labor skills including supervision	x		
State and federal regulation of air quality	x		
Restrictions on disposal of ash and residue	x		
Limit markets for available products			
Siting restrictions	x		
Franchise restrictions on steam and electric sales	x		
Tax subsidies for virgin materials	x		
Price controls on oil and gas	x		
Lack of futures markets for scrap	x		
Unpriced mining and processing costs	x		
Differential freight rates	x		
Lack of product standards for reclaimed materials	x		
Rate regulation of electric utilities	x		
Restrictions on use of ash, residue and shredded materials	x		
Product labeling restrictions	x		
Government procurement policies	x		

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of natural gas recovery at the time when oil producers flared natural gas, considering it a nuisance. If landfill gas recovery does prove economical, it seems likely that solid waste disposal techniques will also be affected. The Mountain View landfill was not designed with methane recovery in mind; consequently it has not been built and operated so as to optimize the production of gas. This has probably had some effect on the rate at which recovery can take place.

In a negative sense, certain impediments related to markets for processed gas have had some effect on PG&E's experience at Mountain View. The landfill is immediately adjacent to a gas transmission line, so no cost was incurred to transport the gas. Since this is not often likely to be the case, the Mountain View project may appear more profitable than other operations would. Also, PG&E did not have to find a customer for its product. Had someone else developed the facility, a sale price would have had to be established. This price would have been less than PG&E's marginal cost for gas by some amount reflecting the risk incurred by PG&E for introducing the gas into its transmission line. Since processed landfill gas is a close substitute for natural gas, this risk would have been small, but it would have to be concerned, for example, about corrosion to transmission lines and level of contaminants.

What Changes Would Leave the Facility Economical?

To illustrate the sensitivity of the gas recovery operation's income statement to various parameters, we carry out below some simple calculations. It should be stressed that these represent order of magnitude estimates and do not take into account a variety of factors that would be considered in a more detailed study of the facility. The sensitivity analysis is conducted with respect to the financial results estimated for full operation in 1979 dollars.

Reduced Gasfield Life--

For the 1-Mscfd plant size at the existing facility, a reduction in the life of the gasfield would not make the facility uneconomical, since only a small fraction of the landfill is being tapped, and waste is still being filled. The only additional cost for developing a new field to serve the existing plant would be the cost of drilling additional wells and extending the collection system. Since the cost of the existing wells and collection system ($70,000 originally, plus $11,500 for 15 supplementary wells) is less than estimated annual operating profit ($82,000), then as an extreme case, 33 wells and the collection system could be replaced each year and still leave the operation profitable. More realistically, the life of a gasfield at Mountain View appears to be at least five years, since the field currently under production was generating methane in 1974. If this remains true for a field when gas is extracted, then a reduction in field life to five years would mean drilling 33 additional wells on new land at that time and linking them to the collection system. This would add only (.1477) x (33/15) x ($11,500) = $3,700 to annualized capital cost, so the figures in Table 33 would remain largely unchanged, except that all per ton figures would be halved as waste utilized was doubled.

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For the larger 5-Mscfd plant size, this might not continue to hold true, since a plant with that capacity would tap more than half of the waste at Mountain View. However, as shown in Table 32, there are economies of scale associated with larger plant size as well. Because no operating data are available for the larger plant size, it is beyond the scope of this report to speculate on how the financial statement would be affected.

Reduced Annual Extraction Rate--

In calculating the operating results presented in Table 33, we estimated that 229 Mscf of raw gas would be extracted annually when the facility becomes operational. Each million standard cubic feet of raw gas was then estimated to produce $1,179 in revenue and to cost $91.30 in royalties. Since operating costs appear to change very little with throughput, this means the operation would continue to break even if the extraction rate were reduced by ($82,000)/($1,179 - $91.30) = 75 Mscf annually, or 33 percent. This is equivalent to an on-line performance of 50 percent with a daily extraction rate of 835 kscfd as assumed, or a daily extraction rate of 560 kscfd with an on-line performance of 75 percent as assumed. The on-line performance rate of 50 percent has already been surpassed in recent months, and an extraction rate of 560 kscfd is well within established limits at which both carbon dioxide breakthrough and biological equilibrium occur.

Reduced Thermal Efficiency--

By similar argument, the thermal efficiency of the facility, conservatively estimated above at 65.5 percent, could be reduced by 33 percent to 44 percent before the operation would run at a loss.

Transport Costs--

Although the Mountain View facility is conveniently located adjacent to a PG&E gas transmission line, gas produced at other landfills might have to be piped to transmission lines in either treated or partially treated condition. The current process at Mountain View relies on pipeline gas for fuel, producing a net output of 327 kscfd of treated gas from 835 kscfd of raw gas and 41 kscfd of fuel. If the raw gas source were at some distance from the transmission line, this process would not be used, but it appears from nomographs developed by PG&E (Source [3], pp. 29-31) that under slightly different circumstances the gas from a facility like Mountain View could be transported several miles at less than the net profit of $1.21/MBtu estimated in Table 33.

Reduced Gas Prices--

If new sources of gas became available at regulated domestic prices in sufficient quantity to displace all of the gas currently imported by PG&E, then the transfer price of $4.00/MBtu used in our calculations would have to be adjusted accordingly. If the marginal cost of gas to PG&E fell by 30 percent to less than $2.79 per MBtu, then landfill gas from Mountain View would no longer be economical.

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Combination of Changes--

We have not explicitly considered the possibility that several factors affecting production and cost could change simultaneously. However, since most of our estimates are on the conservative side, this possibility should not materially affect our conclusions.

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APPENDIX

CATALOG OF IMPEDIMENTS TO ECONOMICAL RESOURCE RECOVERY FACILITIES FOR MUNICIPAL SOLID WASTE

INTRODUCTION

The purpose of this appendix is to develop a catalog of the impediments to economical resource recovery facilities for municipal solid waste. The primary purpose of the catalog is to provide a systematic basis for examining the operating histories of the eight facilities we have visited. An additional use for the catalog is as a checklist which identifies factors that may inhibit the initiation of new facilities for resource recovery. Thus, the catalog may also be useful for policy makers concerned with resource recovery and for local officials considering investments in resource recovery facilities.

In preparing this catalog we have attempted, where possible, to make quantitative estimates of the effect of each impediment. In order to accomplish this we have found it necessary to make many assumptions and to assume values for data in certain areas where none now appear to exist. We cannot stress too strongly, therefore, the tentative nature of our estimates. At best the figures provide order of magnitude estimates and should in no way be considered exact or definitive. Considerably more research would be required to develop definitive estimates for some of the impediments, while for others more exact estimates may simply not be possible.

DEFINITIONS

The development of a catalog presupposes a definition for the terms "impediment" and "economical." In our work we have used the term impediment in reference to any factor which may inhibit the initiation or economical operation of a resource recovery facility. We have used the term economical to refer to operation with revenues equal to or in excess of total costs. Strictly speaking, total costs should include not only capital and operating costs but also any "social costs" in the form of externalities generated by the resource recovery facility. Examples of the latter would include air pollution produced during incineration, noise and dust generated by incoming trucks, and nuisance factors associated with the location of the facility. Strict enforcement of state and federal air quality regulations, strict enforcement of local zoning ordinances, and appropriate landscaping and maintenance of the facility should keep these external costs to a minimum. In general we found such practices to be the case at the sites we have visited.

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In our financial calculations we have thus excluded social costs from consideration except where noted.

SOME PERSPECTIVES ON IMPEDIMENTS TO RESOURCE RECOVERY

All of the impediments usually mentioned in reference to resource recovery really fall into three categories:

- impediments which are in fact problems confronting business activity in general (e.g., business cycle fluctuations);
- impediments which simply reflect the kinds of difficulties encountered during the beginning stages of any new industry (e.g., lack of product standards and specifications);
- impediments which are the result of society's pursuit of other goals (e.g., air quality regulations).

This is not to say that removal of these impediments is unwarranted, or that special treatment for resource recovery is not desirable. It merely suggests that the case for changes in government policy or funding must be properly set forth. It is not, however, within the scope of this report to prepare such a case. Rather, it is our objective to identify the impediments, to assess their effects, and to illustrate the magnitude of the changes that would be required to make resource recovery more generally economical.

In taking this point of view, we recognize that some of the factors which we identify as impediments to resource recovery may actually represent socially preferred activities. Air quality regulations, for example, will most definitely increase the cost of resource recovery for most systems employing incineration. Hence, from the point of view of resource recovery, they are an impediment to economical operation, and we would identify them as such. Nonetheless, from society's point of view, the benefits of restricting emissions from resource recovery facilities may outweigh the increased costs. If this is the case, then even though such regulation is an impediment to economical operation, exemption from the regulation would be socially undesirable.

CLASSIFICATION OF IMPEDIMENTS

In developing this catalog we have adopted a system for classifying the different impediments. Among the various possible classification schemes, we have chosen to group impediments according to whether they:

- reduce the quantity or recoverable fraction of waste available to the facility;
- increase the initial cost or restrict the design of the facility;
- affect the cost or efficiency of operations;
- limit the markets for products available from the facility.

As an example, the fact that landfills are often priced below the full social cost of land disposal results in their attracting waste which might otherwise have gone to a recovery facility. We have thus included this impediment in the first category. The use of an alternative system of classification should not appreciably alter our results.

Table 35 below contains a listing of the commonly cited impediments to resource recovery. In organizing the list we have followed the four-way classification system described above. As mentioned previously, other systems of classification could also be used.

Also included in the table is a designation of whether the impediment is common to other kinds of business activities and whether it reflects a conflict among competing social goals. Admittedly, these designations represent personal judgment on our part. However, we believe them to be defensible and illustrative of the reasons why the case for special treatment of resource recovery facilities, if it is to be made, must be carefully set forth.

DISCUSSION OF INDIVIDUAL IMPEDIMENTS

In this section each of the impediments listed in Table 35 is discussed and numerical estimates of their effects are presented. These estimates are drawn primarily from data in the existing literature concerning resource recovery. For many of the impediments, however, the available research and data are limited and thus our estimates are at best order of magnitude approximations.

1. Pricing of Landfills Below Full Social Cost

Although sanitary landfills represent a major improvement over open dump disposal of solid waste, there is still a possibility of environmental damage from landfills if proper planning and operation is not carried out. The major problems which can arise include groundwater pollution, surface water pollution, air pollution, and various public health and safety hazards. To the extent that these problems are not controlled, the resulting damage represents a cost to the society. And, to the extent that a landfill is allowed to operate without proper controls, the price that will be charged for landfill disposal will be lower than the price otherwise required (assuming competitive markets for disposal). As shorthand, we will refer to the former as the nominal price and to the latter as the full price.

The effect of a deviation between the nominal price and the full price is to lower the revenues which a competing resource recovery facility can obtain from tipping fees. The revenue loss, compared to what would be possible if the landfill were charging the full price, can be determined as follows. Let

p = current tipping fee at resource recovery facility

d = deviation between nominal and full price at landfill

R = current tonnage processed at resource recovery facility.

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TABLE 35. LISTING AND CLASSIFICATION OF COMMONLY CITED IMPEDIMENTS

Impediment	Problem common to business activity in general	Problem common to new business activity	Problem due to conflicting social goals
Restrict quantity or composition of waste			
1. Pricing of landfills below full social cost			x
2. Independent source-separation programs			x
3. Returnables policy for bottles and cans			x
4. Fragmentation of local government			x
5. Restrictions on interstatement movement of waste			x
6. Fluctuations in economic conditions	x		
Increase initial cost or restrict design			
7. Inadequacies of available technology		x	
8. High unit cost for equipment and parts		x	
9. Limited design experience		x	
10. Limitations on municipal financing			x
11. Limitations on municipal contracting			x
Affect cost or efficiency of operations			
12. Limited operating experience		x	
13. Limited availability of spare parts		x	
14. Shortage of required labor skills including supervision		x	
15. State and federal regulation of air quality			x
16. Restrictions on disposal of ash and residue			x
Limit markets for available products			
17. Siting restrictions	x		x
18. Franchise restrictions on steam and electric sales			x
19. Tax subsidies for virgin materials			x
20. Price controls on oil and gas			x
21. Export controls on scrap			x
22. Lack of futures markets for scrap		x	
23. Unpriced mining and processing costs			x
24. Differential freight rates			x
25. Lack of product standards for reclaimed materials		x	
26. Rate regulation of electric utilities			x
27. Product labeling restrictions			x
28. Government procurement policies			x

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Now if the landfill were forced by regulation to operate properly, its price would increase by an amount d. This would in turn allow the recovery facility to increase its price from p to $p + \Delta p$ where $\Delta p \leq d$. For $\Delta p < d$, some waste now going to the landfill may instead go to the recovery facility; let this increase be ΔR. The effect of allowing the landfill to charge less than the full price, then, is to reduce the recovery facility's revenues by an amount*

$$d \cdot R \qquad \text{for } \Delta p = d$$

or

$$R \cdot \Delta p + \Delta R \cdot (p + \Delta p) \qquad \text{for } \Delta p < d.$$

In order to assign a quantitative estimate to the above revenue loss we need an estimate of d. If we make the assumption that the landfill regulations proposed in response to RCRA** represent a balancing of the marginal social costs and benefits of alternative levels of control, then the per ton cost of compliance with RCRA would be an estimate of d. A recent study*** has developed estimates of the per ton cost of RCRA compliance for typical landfills in the U.S. These cost estimates are shown in Table 36. Depending on the size of the landfill, and whether or not it is located in an environmentally sensitive area, the per ton incremental cost of compliance (d) is estimated to range from $1.96 to $9.85 (in 1977 dollars). This would represent an increase of from 40 percent to 88 percent of the current baseline cost for landfill operation. It would also represent the approximate per ton loss of revenue for a competing resource recovery facility. Of course these estimates will vary from site to site depending on local land and labor costs.

2. Independent Source-Separation Programs

Many communities in recent years have developed programs for removing bottles, cans and newspapers from the waste stream and selling them to scrap dealers. In some cases the program is a municipal government function, in others it is run by private companies or volunteer groups. The possibility exists that these source-separation programs could reduce the revenues of a resource recovery facility by reducing the volume and changing the composition of the waste it receives. This revenue loss would occur, of course, only if the program were operated independently of the facility so that the facility would not share in the revenues obtained.

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* We have assumed here that the total waste volume generated is unaffected by price changes. To the extent that consumers vary their solid waste production in response to price changes, then the revenue lost would be less than is shown here.

** The Resource Conservation and Recovery Act of 1976, Public Law 94-850.

*** Fred C. Hart Associates, Inc., On the Proposed Guidelines for the Landfill Disposal of Solid Waste, Draft Environmental Impact Statement, March 1979.

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TABLE 36. ILLUSTRATIVE IMPACT OF RCRA GUIDELINES ON MUNICIPAL SOLID WASTE LANDFILL COSTS
(1977 $/ton)

	Site size categories					
	10 tpd		100 tpd		300 tpd	
Required technologies	Sensitive	Non-sensitive	Sensitive	Non-sensitive	Sensitive	Non-sensitive
Gas control						
Vertical impermeable barriers	$ 1.30	$ 1.30	$ 0.30	$ 0.30	$ 0.15	$ 0.15
Leachate control						
Imper. daily cover (off-site source)	5.30	5.30	2.65	2.65	1.75	1.75
Dike construction*	1.20	--	0.28	--	0.15	--
Surface runoff						
Ponding	0.10	--	0.05	--	0.04	--
Dike construction	1.20	--	0.27	--	0.15	--
Monitoring						
Gas monitoring	0.15	0.15	0.03	0.03	0.01	0.01
Groundwater quality monitoring	0.60	0.60	0.10	0.10	0.05	0.05
Total incremental costs	$ 9.85	$ 7.35	$ 3.68	$ 3.08	$ 2.30	$ 1.96
Baseline costs	11.15	11.15	6.65	6.65	3.95	3.95
Total post-guideline costs	$21.00	$18.50	$10.33	$ 9.73	$ 6.25	$ 5.91
Percent increase	88%	66%	55%	46%	58%	50%

* Dike construction costs were divided equally between leachate and surface runoff control functions.

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The revenue loss due to an independent source-separation program (ISSP) depends on several factors. For example, suppose that in the absence of an ISSP, a resource recovery facility could recover and sell 7 percent (by weight) of the incoming waste stream as ferrous scrap and receive a price of $20 per ton. Suppose further than an ISSP would lead to a 25 percent reduction in the quantity of ferrous scrap that could be recovered (e.g., by separating out some fraction of the steel cans). The revenue loss then would be

$$\left(.07\,\frac{\text{tons of scrap}}{\text{ton of MSW}}\right) \times \left(20\,\frac{\text{dollars}}{\text{ton of scrap}}\right) \times \left(.25\,\frac{\text{tons separated}}{\text{tons recoverable}}\right)$$

$$= \$.35 \text{ per ton of MSW.}$$

Table 37 provides a tabulation of the revenue loss for a facility which recovers ferrous scrap, aluminum and glass and also sells refuse-derived fuel. The recovered fractions shown in column 1 are typical of current practice; the prices shown in column 3 are in 1977 dollars; and the percentage reductions shown in column 2 are educated guesses. For example, in the case of ferrous scrap, 50 percent typically occurs in the form of cans so that if half of all cans were source-separated it would yield a 25 percent reduction in recovered scrap. Note also that in the case of source-separated paper, the price and recovered fraction shown are those for its alternative use as RDF.

Clearly the actual revenue loss will depend upon the mix of products recovered by the resource recovery facility and may thus vary from site to site. Price variations and variations in the fractions which can be separated may also differ widely and thus affect the actual loss.

3. Returnables Policy for Bottles and Cans

As an alternative approach for recovering materials and reducing litter, a number of states have adopted laws requiring deposits on beverage containers. The effect of such laws will be to reduce the quantity of bottles and cans in the waste stream and thus reduce the revenues which a recovery facility can obtain from glass, aluminum and ferrous scrap. To calculate the potential revenue loss, we can use the approach presented earlier in Table 37. The calculations for this case are shown in Table 38. Note that all data are the same except the percentage reductions in scrap volumes. We have assumed here that the percentage reductions may be somewhat larger due to a mandatory deposit program compared to a voluntary source-separation program.

4. Fragmentation of Local Government

In many areas of the country the responsibility for collection and disposal of municipal solid waste resides with individual cities and towns rather than with areawide organizations. Even in areas where collection and/or disposal is carried out by private firms, the contracts or franchises are typically granted to the firms by city or town governments. The effect of this division of responsibility is that except in the very largest cities, the

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TABLE 37. ILLUSTRATIVE REVENUE LOSS DUE TO INDEPENDENT SOURCE-SEPARATION

Product	Normally recovered fraction	Percentage reduction due to source-separation	Price per ton of recovered product	Revenue loss per ton of MSW
Ferrous	.07	.25	$ 20.	$ .35
Aluminum	.01	.25	350.	.88
Glass	.07	.25	4.	.07
Paper	.60*	.25	5.50*	.83*
Total	na	na	na	$2.13

* Figures shown are for paper in its alternative use as RDF.

na = Not applicable.

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TABLE 38. ILLUSTRATIVE REVENUE LOSS DUE TO MANDATORY DEPOSITS ON BEVERAGE CONTAINERS

Product	Normally recovered fraction	Percentage reduction due to source-separation	Price per ton of recovered product	Revenue loss per ton of MSW
Ferrous	.07	.40	$ 20.	$ .56
Aluminum	.01	.80	350.	2.80
Glass	.07	.40	4.	.11
Total	na	na	na	$3.47

na = Not applicable.

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volume of waste available within each government jurisdiction is relatively small. For example, a city of 20,000 people will generate solid waste at the rate of about 50 tons per day (tpd), assuming five pounds per person per day. Even a population of 100,000 will generate only about 250 tpd.

Except for the case of modular incinerators, the design capacities for other resource recovery technologies typically fall in the 200- to 3000-tpd range. Furthermore, economies of scale generally favor operation at the middle to upper end of this range, with savings coming from lower unit costs for both capital investment and operation. The implication of this is that individual communities must either join together in the operation and/or supplying of waste to a common resource recovery facility, or else limit themselves to modular incineration or smaller, less efficient versions of large-scale recovery systems.

To determine the "cost" of the division of responsibility for waste disposal we can contrast the unit costs for small versus large-scale resource recovery facilities. In Table 39 below, the estimated unit costs for both smaller and larger versions of five alternative recovery systems are displayed. The unit costs shown represent the tipping fee that would be required for breakeven operation. The costs are in 1977 dollars and are taken from an earlier paper prepared as part of this project.

The cost differentials shown in the table indicate that communities have a sizable financial incentive to develop cooperative approaches in the event they decide to pursue resource recovery. To the extent that state laws, or local political rivalries which may arise from the balkanization of local government, inhibit the pursuit of cooperative approaches, then these cost differentials also indicate the magnitude of the financial penalty which results.

5. Restrictions on Interstate Movement of Waste

To the extent that state or federal laws prohibit the interstate movement of solid waste, the effect on resource recovery will be to inhibit the joint use of a facility by communities separated by a state boundary. The net result then may be that two smaller facilities would have to be built, one in each state, rather than a single large facility. The "cost" of this prohibition then would be the same as that discussed in the preceding section.

6. Seasonal or Business Cycle Fluctuations

An observed pattern of behavior is the variation in waste generation during different seasons of the year or in response to changes in the general economy. For example, it is often found that waste volumes will increase in the spring and summer months because of increased yard wastes and "spring cleaning." Business cycle variations which reduce consumer income and consumer expenditures can also reduce waste volumes compared to normal patterns.

From the viewpoint of resource recovery, seasonal fluctuations in waste volumes pose a problem for design and operation of the facility. At one

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TABLE 39. ILLUSTRATIVE EFFECT OF SMALL-SCALE OPERATION ON RESOURCE RECOVERY COSTS
(1977 $/ton)

	Breakeven tipping fee for		
Facility type*	Smaller design**	Larger design***	Increase in unit cost
Modular incineration	$ 8.83	$ 3.91	$ 4.92
Mass burning waterwall incineration	5.79	3.06	2.73
Semi-suspension waterwall incineration with ferrous recovery	4.68	(.25)	4.93
RDF with ferrous, aluminum and glass recovery	16.43	10.70	5.73
Ferrous, aluminum and glass recovery only	11.25	8.30	2.95

* Incineration systems assume sale of steam.

** 50 tpd for modular incineration; 500 tpd for all others.

*** 100 tpd for modular incineration; 1500 tpd for all others.

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extreme, the facility can be designed with capacity sufficient to process peak waste volumes, with less than capacity operation during other times of the year. Or the facility can be designed to take only "baseload" waste volumes and then plan to landfill some waste during peak months.

To consider the cost impact of seasonal fluctuations, we have assembled cost data for three cases. In case 1 the facility processes 800 tpd (80 tpd for the modular incinerator) with no seasonal variation. In case 2 the facility processes 700 tpd (70 tpd) throughout the year but landfills an additional 300 tpd (30 tpd) during four months of the year. In case 3 the facility processes 1000 tpd (100 tpd) during four months of the year and 700 tpd (70 tpd) during the remainder of the year. In all three cases the annual average daily tonnage is 800 tpd (80 tpd).

The results of our analysis for the three cases are shown in Table 40. Case 1 represents the base case. The cost shown here for each facility represents the tipping fee that would be required for breakeven operation. Cases 2 and 3 are shown in terms of the incremental unit cost for the respective modes of operation. In case 2 the facility is smaller than in case 1 but incurs landfilling costs. In case 3 the facility is larger than in case 1 but can reduce its operations during certain times of the year. In case 3 we assume that operation at an average of 80 percent of the design capacity will result in 20 percent lower revenues and 15 percent lower O&M costs compared to operation at full capacity. O&M will not fall by a full 20 percent because some costs, such as insurance, are likely to be based on design capacity rather than throughput. Note that somewhat perverse results occur for the RDF and materials-only facilities. The breakeven tipping fees for these facilities are so high that shifting to a smaller design and sending some waste to the landfill (at $4/ton) actually lowers unit costs rather than increasing them.

7. Inadequacies of Available Technology

8. High Unit Cost for Equipment and Parts

9. Limited Design and Operating Experience

These three items are symptomatic of the problems which plague any new technology whether it be resource recovery or solid-state electronics. In the initial stages of development the first operating systems are scaled-up versions of smaller pilot plants. As a result, standard design techniques and operating procedures do not exist and must be developed by experimentation. Furthermore, the market for the technologies is small so that production volumes are low and unit costs remain high. While the specific stage of development varies across the recovery technologies now available, there is little disagreement with the contention that few, if any, of the systems now on the market have reached a mature stage.

The combined effect of these various problems is difficult to estimate. At best, one can only see how sensitive the operating results are to particular assumptions about the nature of these problems. For illustrative purposes we have constructed a cost analysis in which the following

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TABLE 40. ILLUSTRATIVE EFFECT OF SEASONAL WASTE FLUCTUATIONS ON UNIT COSTS (1977 $/ton)

Facility type*	Baseline cost for level operation	Incremental cost	
		Baseload design with landfilling	Peak load design
Modular incineration	$ 5.20	$ .55	$ 1.64
Mass burning waterwall incineration	4.60	.19	3.26
Semi-suspension waterwall incineration with ferrous recovery	2.60	.70	3.53
RDF with ferrous, aluminum and glass recovery	13.40	(1.47)	2.66
Ferrous, aluminum and glass recovery only	9.80	(.37)	1.22

* Incineration systems assume sale of steam.

() denotes cost reduction.

assumptions are incorporated: (1) capital costs are 10 percent lower than at present, reflecting lower equipment and plant design costs; (2) O&M costs are 10 percent lower than at present, reflecting lower parts and repairs cost. The results of this analysis are presented in Table 41. The first column shows the baseline costs for each of five facility types. These costs represent the tipping fees required for breakeven operation. The second and third columns show the incremental savings due to the 10 percent reduction in capital and O&M costs, respectively. Note that for at least three of the systems, the relatively small reduction in capital and O&M cost would be sufficient to halve or eliminate the tipping fee required for breakeven operation.

10. Limitations on Municipal Financing

In many states there are statutory or constitutional restrictions on capital expenditures made by local governments. These may include restrictions on methods for issuing debt, allowable levels of debt, or allowable rates of interest. In Iowa, for example, a special act of the legislature was required in order for the Ames facility to be financed with debt bearing interest at a rate in excess of 5 percent. In the case of publicly-owned resource recovery plants, these limitations can result in delays to the project, with an associated increase in project costs, or possibly result in the use of less attractive methods of finance, again with an increase in cost.

To illustrate the potential effect of these limitations we have constructed two hypothetical cases. In the first case we consider the effects of a six-month delay in project initiation due, for example, to the need for voter approval of a bond issue, or perhaps action by the state legislature. In the second case we consider the effects of using revenue bonds rather than general obligation bonds, under the assumption that use of the latter is prevented by debt limitation. For illustrative purposes, the capital cost of the facility is assumed to be $25 million, and the annual throughput 260,000 tons (1000 tpd).

Case 1 - Six-Month Delay

Initial capital cost		$25,000,000
Nominal escalation rate	1% per month	
General inflation rate	.5% per month	
Real escalation rate	$\frac{.01 - .005}{1 + .005}$	

Real cost increase [(1.005) - 1] . ($25,000,000) = $759,000

Amortized real cost increase (7% - 20 years) = $71,600 per year

Per ton real cost increase ($71,600) (260,000) = **$.28 per ton**

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TABLE 41. ILLUSTRATIVE COST REDUCTIONS POSSIBLE WITH INCREASED MANUFACTURING, DESIGN AND OPERATING EXPERIENCE
(1977 $/ton)

Facility type*	Baseline cost	Incremental savings for 10 percent reduction in		Total savings
		Capital cost	O&M cost	
Modular incineration	$ 3.91	$ .84	$ 1.35	$ 2.19
Mass burning waterwall incineration	4.00	1.30	.87	2.17
Semi-suspension waterwall incineration with ferrous recovery	1.53	1.58	1.04	2.62
RDF with ferrous, aluminum and glass recovery	12.58	1.05	.86	1.91
Ferrous, aluminum and glass recovery only	9.25	.47	.80	1.27

* 100 tpd for modular incineration; 1000 tpd for all others. Incineration systems assume sale of steam.

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Case 2 - Revenue Bonds vs. General Obligation Bonds

Initial capital cost	$25,000,000
Revenue bond amortization (7% - 20 years)	$2,360,000
GO bond amortization (6 1/2% - 20 years)	$2,269,000
Annual cost difference	$91,000
Per ton cost difference ($91,000) (260,000) =	$.35 per ton

11. Limitations on Municipal Contracting

Limitations on municipal contracting, as compared to limitations on financing, may take several forms. The first of these may be a requirement that municipal contracts be awarded on the basis of low bid. If so, this could provide contractors with an incentive to "cut corners" on their designs with the result that initial costs may be lower at the expense of higher repair and maintenance costs later on. A second limitation may be in the form of a restriction on the signing of long-term contracts. This type of restriction could prevent a community from entering into a long-term agreement to supply waste to a recovery facility. It could also prevent long-term contracting for operation of a facility by a private firm.

To illustrate the effects of low bid requirements, consider the following illustrative situation. Suppose a well-designed facility would cost $25 million and require $2.5 million per year for operation and maintenance. At a cost of capital of 7 percent, how big an increase in O&M expense would a city accept in exchange for a given percentage reduction in initial capital cost? Some sample cases are provided below in Table 42.

TABLE 42. TRADEOFF BETWEEN LOW FIRST BID AND HIGHER O&M

Percent reduction in capital cost	Annual value of reduction (7%-20 years)	Equivalent percent increase in O&M
1	$ 23,600	.94
5	118,000	4.7
10	236,000	9.4
20	472,000	18.9

As can be seen in the table, a city should be indifferent between the "well-designed" facility and one costing, say, 5 percent less but incurring 4.7 percent higher O&M costs. If the 5 percent capital saving resulted in more than a 4.7 percent increase, then the well-designed facility should be preferred.

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We have not attempted to quantify the effects of limitations on long-term contracting. Our understanding is that this is becoming less of a problem as states have begun to reexamine these restrictions.

12. Limited Operating Experience

13. Limited Availability of Spare Parts

14. Shortage of Labor and Managerial Skills

These issues have already been dealt with in the discussion of impediments numbered 7 through 9.

15. State and Federal Regulation of Air Quality

State and federal regulation of air quality can affect resource recovery in several ways. It may require that electrostatic precipitators or baghouses be installed to control particulate emissions from recovery facilities employing incineration technology. In more extreme situations, where "offset" requirements are in effect, the construction of the facility may be prohibited. In the latter case, construction would be possible only if agreement could be reached with another air pollution source(s) for an equivalent reduction (offset) in that source's emissions.

Air quality regulations can also affect resource recovery in more indirect ways. In the northeast, for example, air quality regulation has substantially limited the use of coal in utility and industrial combustors built in the 1970's. Most installations have instead used oil, gas or nuclear fuels. As a result, the market for RDF in co-firing applications with coal is virtually non-existent in the northeast.

By contrast, in areas which have traditionally used coal, air quality regulation may be a help rather than a hindrance. In these areas, RDF, which is low in sulfur, may offer an alternative to scrubbers or low sulfur western coal in facilities now using higher sulfur coals. This consideration was present, in fact, in the initial planning in the Ames, Iowa facility.

To consider the effect of requiring the installation of electrostatic precipitators (ESP), we can construct an example cost analysis. The basic cost for ESP equipment will be about $20,000 per ton per hour (tph) of incinerator capacity (1977 $/ton). Installation and other indirect costs will raise this to about $30,000 per tph of capacity. On an annual basis, assuming amortization at 7 percent over 20 years, the annual cost will be about $2,830 per tph. Annual operation for 6000 hours per year would mean that the precipitators add ($2,839) ÷ (6000) = $.47 per ton to the processing costs of the facility.

The cost impact of offset requirements are more difficult to estimate. As a rough approximation, one could assume that the recovery facility will incur the $.47 per ton cost for its own facility, plus costs of the same order of magnitude for additional control equipment applied to an existing air

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pollution source. A total cost on the order of $1.00 per ton is thus probably not unreasonable.

The cost impact due to a limited market for RDF is also difficult to estimate. At one extreme, if no RDF market can be found, then the revenue loss would be:

$$\left(\begin{array}{c}\$5.50 \text{ per ton}\\ \text{of RDF}\end{array}\right) \times \left(.60\ \frac{\text{tons of RDF}}{\text{ton of MSW}}\right) = \$3.30 \text{ per ton of MSW.}$$

On the other hand, the lack of an RDF market may simply mean that the recovery facility must generate and sell steam if it is to be involved in energy recovery. Our cost estimates suggest that incineration systems are more economical than RDF systems anyway. Hence if a steam market exists, the construction of a steam facility rather than an RDF facility would mean the cost impact in an opportunity cost sense would be $0.

We should add, of course, that air quality regulations represent the government's efforts to force air pollution sources to internalize the social costs which air pollution imposes on society. Hence, the cost of air pollution controls is not an "impediment" in the sense of the definition stated at the beginning of this paper. That is, air quality regulations do not impede "economical" operation where economical operation means revenues in excess of total costs including any social costs. The regulations simply force the facility to bear its total costs of operation.

16. Restrictions on Disposal of Ash and Residue

The waste remaining after incineration and materials recovery can represent 25 percent or more of the incoming waste by weight. There have been some investigations into the use of this ash and/or residue for road building or as daily cover material for landfills. In some states, however, its use for these purposes is prohibited, implying that it must instead be landfilled and covered. The effect of these restrictions, then, is to make ash and residue disposal an additional expense for the recovery facility as opposed to a source of revenue.

Depending on the type of resource recovery facility and the price of landfill disposal, the impact of restrictions on ash and residue disposal will vary. If r is the fraction of incoming waste which must be disposed of as ash or residue and p is the landfill tipping fee, then $r \cdot p$ represents the cost of ash and residue disposal per ton of incoming waste. In Table 43 below, this calculation is carried out for five types of resource recovery facilities, assuming a landfill price of $4 per ton (1977). These figures, shown in the first column, represent a lower bound on the impact of these restrictions. To obtain an upper bound, one must add to these numbers the revenue loss from restrictions on alternative uses. If g is the selling price for ash and residue in an alternative use such as road building, then the revenue loss is given by $r \cdot g$ and the total impact of the restriction is given by $r \cdot (p + g)$. These calculations are provided in the second and third columns of the table.

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TABLE 43. ILLUSTRATIVE EFFECT OF RESTRICTIONS ON ASH AND RESIDUE DISPOSAL (1977 $/ton MSW)

Facility type	Fraction of ash and residue	Cost of landfill disposal	Revenue loss	Total impact
Modular incineration	.33	$ 1.32	$ .33	$ 1.65
Mass burning waterwall incineration	.33	$ 1.32	.33	1.65
Semi-suspension waterwall incineration with ferrous recovery	.20	.80	.20	1.00
RDF with ferrous, aluminum and glass recovery	.055	.22	.06	.28
Ferrous, eluminum and glass recovery only	.86	3.44	.86	4.30

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The calculations assume a selling price of $1 per ton (1977) for ash and residue.

17. Siting Restrictions

The siting of a resource recovery facility can be subject to a variety of restrictions. These may range from local zoning ordinances to state and federal regulations of the siting of power plants and combustion equipment. At a minimum, these restrictions will increase the length of time required for obtaining a suitable location, with attendant costs for delay as estimated previously in section 10. In a worst case situation, the facility may even be precluded from entering certain markets because of the locational restrictions placed upon it. For example, a facility designed to produce low temperature steam for a central city district heating system may find that the cost of constructing a steam line is prohibitively expensive if the facility were forced to locate on the outskirts of town.

The effect of time delays on facility cost was estimated earlier in section 10. In this section, the effect of siting restrictions on steam transport cost is examined. The basis for the cost estimates are the consulting engineer's report on the Harrisburg steam line.

The consulting engineer for Harrisburg estimated an installed cost of $3.64 million for a 2.43-mile steam line capable of transporting 200,000 lb/hr of steam entering at 250 psig and losing no more than 60 psig during transport. The line serves a utility steam plant within a few blocks of the state capitol and may thus be considered typical of central city construction problems. Escalated to 1977 and amortized over 20 years at 7 percent, the annual cost of the line per mile would be $171,000. This is approximately $855 per mile per year per 1000 lb/hr of steam capacity.

As an example, a 1000-tpd facility could generate about 250,000 lb/hr of steam assuming three pounds of steam per pound of MSW. Assuming all of this were available for export, the annual per mile cost of a steam line would be $214,000. If the facility averaged 800 tpd throughput for 360 days, the annual cost of the steam line would be $.74 per mile per ton of MSW. Thus, if the facility were located, say, five miles from the district heating system, the steam line would add $3.70 per ton to the required tipping fee.

18. Franchises for Steam and Electricity Sales

In most or all states the rights to sell electricity within a given geographic area are granted to specific electric utilities. In many states the rights to sell steam are similarly protected by state-granted franchises. Thus a resource recovery facility which would like to sell either electricity or steam may find that it is prevented from doing so by existing steam or electricity franchises.

One solution to franchise restrictions would be to sell directly to the utility which would then resell the product. We note, however, that not all utilities are interested in such an arrangement. An alternative solution, in the case of electricity only, would be to locate a utility which is interested

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in buying, and then wheel (transport) the power to that utility, across the transmission lines of intermediate utilities. If neither of these solutions is possible, or if special relief cannot be obtained from the state public utility commission, then the steam and electricity markets may simply be foreclosed.

The loss of steam and electricity markets would eliminate the two potentially largest revenue sources for resource recovery. As shown in Table 44, the revenue potential from steam or electricity sales considerably exceeds the potential from other products. Revenues from steam could be as much as \$18 per ton of MSW and \$6 per ton for electricity. This compares with \$3 to \$4 or less from materials recovery. Of course the cost of "recovering" steam and electricity is higher also and must be factored into an overall analysis. Nonetheless, the loss of these markets would reduce potential revenues significantly as suggested in the table.

19. Tax Subsidies for Virgin Materials

The federal tax code contains a number of special provisions which reduce the tax liability of private producers of virgin materials. These provisions include, for example: percentage depletion allowances, expensing of exploration and development costs, capital gains treatment of certain income and other related provisions. By lowering the net production cost, and thus the price of virgin materials, these tax provisions increase the demand for virgin materials at the expense of scrap materials which generally do not receive similar tax treatment.

The effect of tax subsidies for virgin materials can be illustrated via a simple model of the virgin and scrap materials markets. For simplicity, we assume that the functional forms for supply and demand can be written as follows:

(1) Virgin supply: $P_v = a_0 + a_1 Q_v^{a_2} W_v^{a_3}$

(2) Scrap supply: $P_s = c_0 + c_1 Q_s^{c_2} W_s^{c_3}$

(3) Virgin demand: $Q_v = b_0 P_v^{b_1} P_s^{b_2} Z_v^{b_3}$

(4) Scrap demand: $Q_s = d_0 P_s^{d_1} P_v^{d_2} Z_s^{d_3}$

where P_v and P_s are virgin and scrap prices,

Q_v and Q_s are virgin and scrap quantities,

W_v, W_s, Z_v and Z_s are other variables affecting supply and demand, and

the a_i, b_i, c_i and d_i are constants.

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TABLE 44. ILLUSTRATIVE REVENUE POTENTIAL FROM RECOVERED PRODUCTS

Product	Recovery rate per ton of MSW	Price per unit of product	Revenue per ton of MSW
Steam	6000 lbs	$ 3/1000 lbs	$18.
Electricity	300 kWh	2¢/kWh	$ 6.
Aluminum	0.01 tons	$350/ton	$ 3.50
RDF	0.6 tons	$ 5.50/ton	$ 3.30
Ferrous	0.07 tons	$ 20/ton	$ 1.40
Glass	0.07 tons	$ 4/ton	$ 0.28
Methane	0.8 MBtu	$ 3/MBtu	$ 2.40

Note: Revenues are gross of recovery costs.

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In the model above, the effect of a tax subsidy for virgin materials will typically be to change the values of the coefficients a_0 and a_1 in the virgin supply equation. For example, the existence of a percentage depletion allowance would have the effect of decreasing the virgin supply price by a constant percentage amount, or equivalently, of decreasing the values of a_0 and a_1, compared to the situation without the depletion allowance. By solving the system of equations for the equilibrium prices and quantities, one could in theory trace out the effect of this subsidy on scrap prices and demand.

In one previous study,* an effort was made to estimate the impact of various tax subsidies on scrap demand and prices. The overall conclusion was that the short-run effect of eliminating the subsidies would be quite small. These conclusions were based on estimates of essentially short-run elasticities. That is, they reflect supply and demand behavior within the constraints of existing plant and equipment. It is conceivable that long-run elasticities may be considerably larger. That is, a change in the relative prices for scrap and virgin materials may alter investment patterns such that substitution of scrap for virgin material could increase to a larger extent. It is not possible to assess these possibilities, however, within the limits of existing research.

20. Price Controls on Oil and Gas

In the U.S., the prices for domestically produced oil and natural gas are regulated to varying extents. The argument is sometimes made that as a result average oil and gas prices are lower than they would otherwise be and hence so is the price which can be obtained for RDF or steam generated from waste. The elements of this argument are summarized below for the case of oil; the elements are similar for the case of natural gas. The important point, as we shall see, is that the price controls must be in place at both the production and retail levels for the argument to hold. If only crude oil prices (or wellhead prices for gas) are controlled, and retail prices are not directly or indirectly controlled, then the effect of the controls would be to raise the demand price for energy from refuse.

Consider what the situation would be if there were no price controls and no restrictions on the importing of oil. In this case the prices for crude oil in both domestic and world markets would be identical except for differences due to quality variations or transportation costs. Furthermore, most analyses suggest that in this situation the U.S. would still be importing some oil to satisfy domestic demand.

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* R. C. Anderson and R. D. Spiegelman, Impact of the Federal Tax Code On Resource Recovery, PB 264 886, 1976 and U.S. Treasury Department, Office of Tax Analysis, Federal Tax Policy and Recycling of Solid Waste Materials, 1979.

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Now suppose that the U.S. instead has regulations which hold the allowable prices for domestic crude oil at some level below the free market equilibrium. In this situation, domestic producers would supply less oil compared to the free market case and the additional demand would have to be supplied from imports. Because the domestic demand for imports would now be higher than in the free market case, the price of imports would also rise to a higher level. Furthermore, the marginal price of crude oil would now be equal to the import price, higher than the regulated domestic crude oil price and higher than the "average" crude oil price. In the free market case, all four of these prices are equal.

Consider further what happens to the prices for refined products when the price of crude oil is controlled but there are no controls on retail product prices. In this case, refiners who must rely primarily on imported crude will find it necessary to charge a higher price for products compared to refiners which have access to controlled crude. In this situation, the latter refiners may be able to raise their product prices to the level charged by the refiners using primarily imported crude and in so doing earn an economic rent. Because product prices will thus tend towards the level charged by the refiners using imported crude, and because the marginal price of imported crude is higher than in the case where there are no controls on crude oil prices, then product prices will tend to be higher compared to the unregulated case. In this situation, firms would be willing to pay a higher price for RDF than in the fully unregulated case because they face higher prices for refined products.

If instead of the above case, we have the situation in which there are controls on both crude oil prices and refined product prices, then average product prices will be lower than in the fully unregulated case. This occurs because the crude oil price controls lower the average price of crude and the retail price controls force the retail prices to be based on cost. In this situation, the downward pressure on refined product prices lowers the demand price which firms would be willing to pay for RDF or steam generated from waste.

The arguments above assume that in both the regulated and free market cases there are no price or quantity restrictions on imports. If there are quantity restrictions (as the Carter Administration has proposed), the effect would be to raise the price of imported crude in both the regulated and free market cases. This would increase both the marginal and average prices of crude oil in both cases, and hence put upward pressure on product prices and thus RDF prices. If there are price restrictions on imports (e.g., additional taxes), the net price of an imported barrel would again be higher in both cases, again forcing up both the marginal and average prices.

While the effect of price controls is relatively easy to predict in theory, the actual situation in the U.S. is somewhat more complicated for two reasons. First, although crude oil price controls are still in effect, and controls on the prices of refined products were also put in place, price controls for certain refined products have subsequently been removed. One refined product category which has been decontrolled is residual oil, which is used largely as boiler fuel and hence competes directly with RDF and with

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steam generated from waste. With controls on residual oil prices removed, the net effect of the regulatory program would be to raise residual oil prices above the free market price (because of the controls on domestic crude oil prices), and hence to raise the demand price for RDF above its free market price. Running counter to this effect, however, is the impact of the so-called "entitlements" program. The entitlements program, which is a system of transfer payments among refiners, is designed to equalize crude oil costs among refiners so that all refiners face the same average crude oil cost. To the extent that the entitlements program thus encourages pricing based on average crude oil cost, the entitlements program, together with the controls on crude oil prices, will depress residual oil prices below the free market price, even in the absence of direct controls on residual oil prices. Hence, it is most likely the case that residual oil prices are below the free market price, implying that the demand price for RDF is lower than it would be if all controls were removed and the entitlements program were abolished.

21. Export Controls on Scrap

At the present time, the U.S. government does not restrict the export of scrap metal such as ferrous or aluminum scrap. The current situation thus does not represent an impediment per se. Should such controls be imposed in the future, however, the effect would be to depress the demand price for scrap by limiting the export segment of the scrap market. A lowering of scrap prices would in turn reduce the revenues available to a resource recovery facility engaged in scrap metal recovery.

22. Lack of Futures Markets for Scrap

Futures markets, in general, serve several functions. They provide an organized system for gathering and exchanging information about future price expectations. They enable buyers and sellers of commodities to hedge against losses caused by unexpected price fluctuations. And in some cases they may also have a stabilizing effect on real cash prices for commodities. In a commodity market where no trading in futures occurs, the level of price uncertainty is thus likely to be greater and the risk of dealing in the commodity more substantial. The higher degree of risk may in turn discourage the use of the commodity compared to substitutes with more stable prices.

At the present time no organized futures markets exist for any of the materials typically marketed by a resource recovery facility. Trade in these commodities is characterized by volatile price fluctuations which have in the past been less predictable than prices for the substitute primary materials. Although no estimates exist of the extent to which price fluctuation may have reduced demand and prices for recovered materials, some sample calculations can illustrate the potential effect.

Consider, for example, what the per ton loss in revenues is if scrap ferrous prices are currently 10 percent lower than they would be if an organized futures market existed. If the current price is \$20 per ton for ferrous scrap, then the price with a futures market would be \$20/1-.1) = \$22.22. With current practice, approximately 7 percent of incoming waste can be recovered as ferrous scrap. The per ton revenue loss is (22.22 - 20) (.07)

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= $.16 per ton of MSW. The potential revenue loss for various hypothetical reductions in the price for recovered materials is summarized in Table 45.

23. Unpriced Mining and Processing Costs

The mining and processing of virgin materials can often result in environmental and other impacts which are substantially greater than would be the case from the use of recovered materials. It is estimated, for example, that steel produced from scrap results in an 86 percent reduction in air pollution effluents, a 76 percent reduction in water pollution effluents, and a 97 percent reduction in mining wastes, compared to steel produced using virgin ore. To the extent that steel and ore products utilize adequate environmental controls, the price of virgin-based steel will internalize these external costs. However, to the extent that adequate controls are not utilized, the external costs will not be reflected in the price of virgin-based steel and an unfair advantage over scrap-based steel will result. This in turn would lower the demand and price for recovered scrap.

The extent to which virgin material prices do not reflect fully internalized external costs has not been systematically determined. Consequently, nor have the resulting reductions in scrap prices been estimated. As in the preceding section, however, sample calculations can illustrate the potential revenue loss for varying assumptions about the reduction in scrap prices. These sample calculations are provided in Table 46. Note that Table 46 is an expansion of Table 45 to include energy products recovered from municipal solid waste. RDF, for example, competes with coal and other fuels which may not fully internalize the environmental, public health and other impacts involved in their extraction and processing.

24. Differential Freight Rates for Virgin and Secondary Materials

Considerable attention has been given to the fact that secondary materials are often charged higher rates for shipping, particularly by railroads subject to rate regulation by the Interstate Commerce Commission. An EPA-contracted study found that rail rates for scrap iron, for example, were considerably higher than for iron ore ($7.71/ton vs. $2.39/ton for shipments of 500 miles).* The study noted, however, that some of the difference could be accounted for by the higher cost to the railroad for shipping scrap vs. ore. Yet, when the higher costs were taken into account, it was found that the ratio of revenue to variable cost for iron ore was still lower than for scrap iron and steel (1.33 vs. 1.94 for shipments of 500 miles).

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* Moshman Associates, Inc., An Analysis of Transportation Rates and Costs for Selected Virgin and Secondary Commodities, September 1973.

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TABLE 45. ILLUSTRATIVE REVENUE LOSS IF LACK OF FUTURES MARKETS HAVE DEPRESSED CURRENT SCRAP PRICES
(1977 $/ton)

Recovered product	Recovery rate per ton of MSW	Current price per ton of product	Revenue loss per ton of MSW for given product price reductions	
			10%	25%
Ferrous	.07	$ 20.	$ .16	$ .47
Aluminum	.01	350.	.39	1.17
Glass	.07	4.	.03	.09

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TABLE 46. ILLUSTRATIVE REVENUE LOSSES IF VIRGIN MATERIAL PRICES DO NOT REFLECT FULL SOCIAL COSTS AND DEPRESS SECONDARY MATERIAL PRICES AS A RESULT
(1977 $/ton)

Recovered product	Recovery rate per ton of MSW	Current price per ton of product	Revenue loss per ton of MSW for given product price reductions	
			10%	25%
Ferrous	.07 tons	$ 20.	$ .16	$ .47
Aluminum	.01 tons	350.	.39	1.17
Glass	.07 tons	4.	.03	.09
Paper	.15 tons	30.	.50	1.50
RDF	.60 tons	5.50	.37	1.10
Steam	6 klbs	3.	2.00	6.00
Electricity	300 kWh	0.02	.67	2.00

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In a freely competitive market for transportation services, one would expect competition to force rates to be based on cost of service and hence to eliminate the differentials observed between revenue to variable cost ratios for different commodities. The fact that such differentials do exist implies that the ICC either explicitly or implicitly allows the railroads to deviate to some extent from pricing based on cost of service. In either case, some secondary materials are put at a disadvantage as a result.

To evaluate the impact of differential freight rates on resource recovery, a series of calculations is carried out in Table 47 below. The calculations can be described as follows. Let r_i, c_i, and x_i be the revenue per ton, variable cost per ton, and the ratio of revenue to variable cost, for commodity type i (i = 1 for virgin, i = 2 for secondary). Let Δ be the increase required in the freight rate for the virgin material such that the ratio of revenue to variable cost is equal to that for the secondary material. That is,

$$\frac{r_1}{c_1} = x_1 , \quad \frac{r_2}{c_2} = x_2 \quad \text{and} \quad \frac{\left(r_1 + \Delta\right)}{c_1} = x_2$$

By appropriate algebra one can solve for Δ as

$$\Delta = r_1 \cdot \left(\frac{x_2}{x_1} - 1\right) .$$

As an example, in the previously cited study, it was found that (in 1969) for iron ore $r_1 = \$4.76$ and $x_1 = 1.33$, for scrap iron $x_2 = 1.94$, and thus $\Delta = \$2.18$. Iron ore, however, represents only about 20 percent of the production cost for pig iron, the latter being the commodity for which scrap iron is a substitute. Hence if freight rates for iron ore were raised by $2.18 per ton, the price of pig iron would rise by no more than (.20) ($2.18) = $.44 per ton. The latter represents the amount by which scrap iron prices could be increased if freight rates for iron ore were raised by $2.18.

25. Lack of Product Standards for Reclaimed Materials

The lack of product standards for reclaimed materials can impede the development of markets, including futures markets, for reclaimed materials. In the absence of product standards, a buyer cannot be sure that RDF, for example, will have the same energy content or contain the same quantity and kind of non-combustibles as RDF which may be supplied by another source. Hence the price which the buyer may be willing to pay may be lower than if the precise characteristics of the RDF could be known in advance and could be expected to show little variability from purchase to purchase. The lack of standards is particularly critical for resource recovery facilities, compared to other sources of scrap material, because mixed municipal solid waste is seldom homogeneous throughout the year, much less across different facilities. The American Society for Testing and Materials (ASTM) has a program underway to address this problem by developing standards for a variety of recovered materials from mixed municipal solid waste. Until such standards have been

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TABLE 47. ILLUSTRATIVE EFFECT OF REQUIRING PARITY BETWEEN FREIGHT RATES FOR VIRGIN AND SECONDARY MATERIALS
(1977 $/ton)

Product	Freight rate[1] per ton (r_1)	Ratio of revenue[2] to variable cost (X_1)	Δ^3	Scrap recovery rate per ton of MSW	Revenue impact per ton of MSW[4]
Iron ore	$ 4.76	$1.33			
Iron and steel scrap	15.35	1.94	$ 2.18	.07	$ .03[5]
Wood pulp	17.10	2.43	- 5.47	.15	- .82
Waste paper	14.06	1.66			
Glass sand	13.66	1.45			
Glass cullet	17.58	1.94	4.64	.07	.32
Aluminum ingot	36.77	2.38			
Aluminum scrap	32.19	1.72	-10.30	.01	- .10

1. Rates shown are based on 1969 rates, escalated to 1977 using a rail freight cost index.
2. Ratios are for 1969, and for shipping distance of 500 miles.
3. For definition see text.
4. Minus sign indicates differential favors scrap rather than virgin material.
5. Adjusted to account for the fact that iron ore represents 20 percent of pig iron production cost; i.e., ($2.18) (.07) (.20) = $.03.

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developed, the existing uncertainty about product characteristics would depress prices to some degree to offset the riskiness perceived by potential buyers. Some illustrative calculations indicating the potential revenue loss which might result from this uncertainty were presented earlier in section 22 of this appendix.

26. Rate Regulation of Electric Utilities

One of the potentially attractive markets for RDF is the electric utility industry by virtue of its significant fuel requirements and technical expertise in fuel handling and combustion. Existing practices for regulating electric utility rates have, however, reduced the incentive for electric utilities to use RDF as a regular fuel source. Foremost among the problems present is the widespread use of fuel-adjustment clauses which allow utilities to pass increases in fuel costs along to customers without formal regulatory review. These clauses thus reduce the incentive for a utility to identify and use lower cost fuels such as RDF since higher fuel costs do not directly reduce profits. In addition, since utilities are allowed to earn some fixed rate of return on invested capital, then any fuel cost savings which might initially increase the return on investment may eventually be offset by a reduction in allowed earnings elsewhere in the company.

Another feature of current regulatory practices is that they may reduce the incentives for utilities to invest in risky activities and hence reduce the extent to which utilities might invest in innovative technologies such as RDF-fired steam electric generating plants. While the effect of regulation on innovation is still being debated in the literature, the mechanisms by which incentives may be affected would include the following: utility commissions may not allow the higher than normal rates of return that would be required to compensate a utility for undertaking a riskier than normal investment; reliability of service, which is a primary requirement placed on electric utilities, may be adversely affected by the use of an RDF-fired unit if such units prove to have lower reliability than more conventional equipment; regulation may induce a bias in the relative utilization of different factor inputs (capital vs. labor vs. fuel) and thus affect the relative desirability of different investments.

27. Product Labeling Restrictions

28. Government Procurement Policies

These items represent issues which at various times have been mentioned as potential impediments to resource recovery. The issue of product labeling restrictions concerns whether government labeling requirements may unduly discourage the use of products containing reclaimed materials. Examples include lubricating oil containing re-refined waste oil, bedding and upholstery containing reclaimed fibers, and clothing and other fabrics containing reclaimed fibers. The issue is not one of whether the material content should be disclosed, but rather whether the required labeling performs the disclosure in a way which implies that products containing reclaimed materials are inherently inferior.

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The issue of government procurement policies concerns whether federal government procurement specifications might be overly restrictive and arbitrarily exclude the possibility of purchasing items which contain recycled materials, but which in all other substantive respects meet the required performance standards. The issue has been viewed as important in the past, not only because the federal government is a large consumer of products, but also because federal procurement specifications are often the model for procurement by state and local governments and private industries. More recently, however, federal agencies have been directed by the Resource Conservation and Recovery Act to revise their procurement practices to encourage the use of products containing the maximum percent of recycled material practicable. Assuming that provisions of the law are enforced, this issue should be of lesser significance as an impediment to resource recovery in the future.